



INSTITUTE FOR DEFENSE ANALYSES

**Life Cycle Processes: Standards, Capability
and Maturity Models, Process Improvement
Models, and Appraisal Methods**

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PREFACE

This document supports work performed by the Institute for Defense Analyses (IDA) in partial fulfillment of the task titled “Analysis of System Life Cycle Processes.” The work was sponsored over several years by the Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics), Office of Interoperability (IO), Office of Systems Acquisition (SA), and the Office of the Director, Test, Systems Engineering, and Evaluation.

This document summarizes the myriad of life-cycle-process standards; capability and maturity models; process improvement models; and appraisal, assessment, and evaluation methods that have been developed and used by industry and the Department of Defense. The Institute for Defense Analyses (IDA) has compiled this document in an effort to clarify and document the background, purpose, and status of the organizations, standards, models, and appraisal methods related to life cycle processes.

This document was reviewed by Mr. Lance Hancock of the System Evaluation Division of IDA.

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SUMMARY

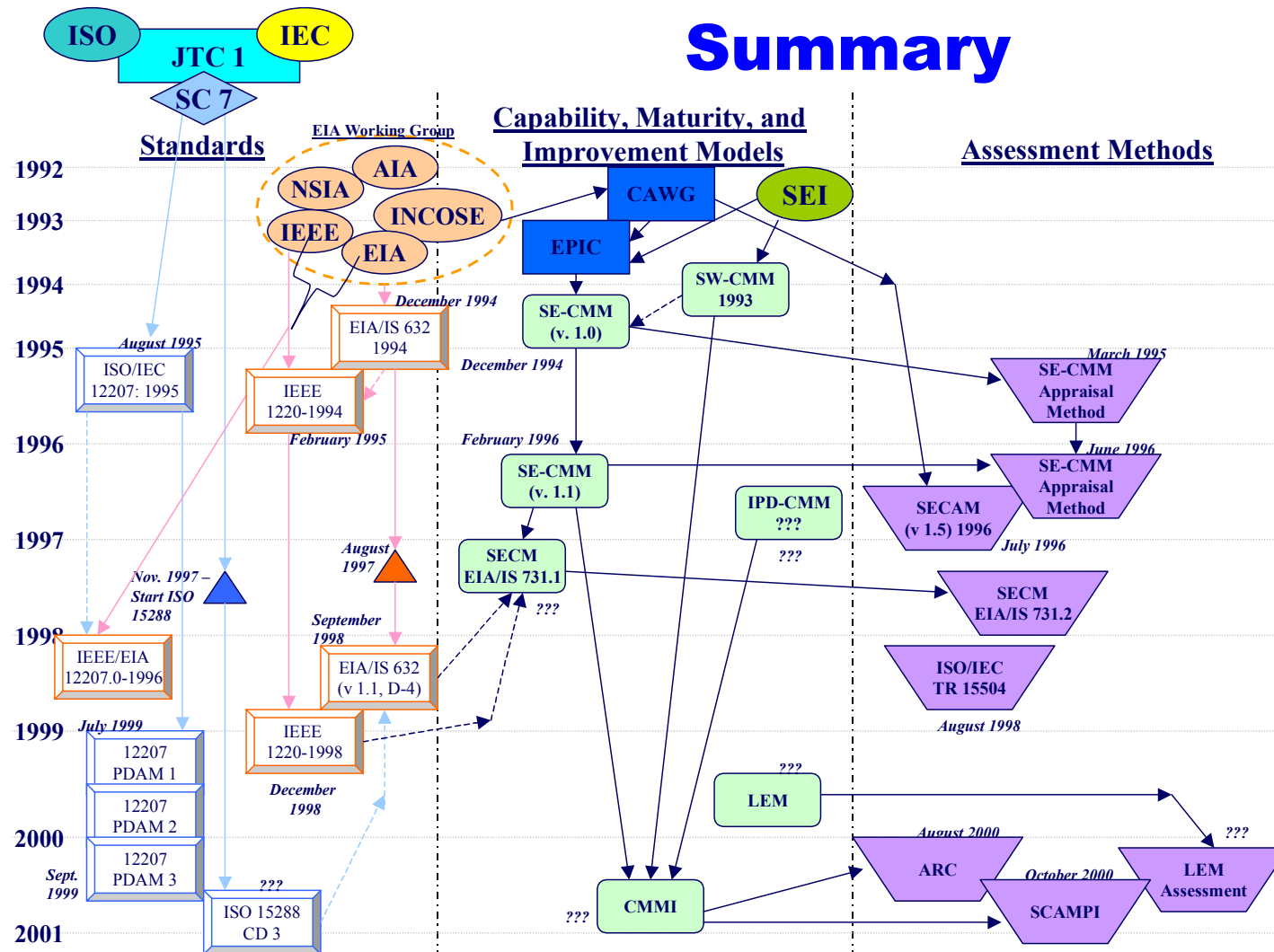
A multitude of international, national, and industry-level organizations have addressed life cycle processes. These efforts have been formalized in many different life cycle process standards, models, and appraisal methods. The accompanying diagram provides an overview of how these standards, models, and appraisal methods have developed over the past decade, as well as the interrelationships that exist between them (see Appendix A for acronym and abbreviation definitions). This multitude of often overlapping standards, models, and assessment methods has been dubbed “the standards quagmire.”¹ This document presents information on the various international and national organizations, standards, process models, capability models, maturity models, process improvement models, and appraisal methods that make up this complex picture in an effort to provide a concise snapshot of the backgrounds, purpose, status, and relationships among the many entities.

The document is organized into five sections:

- Relevant Organizations
- Standards for Life Cycle Processes
- Capability and Maturity Models
- Process Improvement Models
- Appraisal Methods

Having many standards and models leads to multiple assessments, evaluations, and appraisals against those standards and models. DoD’s Office of Systems Engineering sought to eliminate many duplicative appraisals and improve process performance for both software and systems development by sponsoring a Capability Maturity Model Integration (CMMI) project with industry and the Software Engineering Institute. This document provides much of the background information for that project.

¹ Sarah Sheard, “The Frameworks Quagmire,” *CrossTalk*, <http://www.stsc.hill.af.mil/CrossTalk/1997/sep/frameworks.htm>.



The first section describes the relevant organizations involved in life cycle process modeling.

Relevant Organizations

- International Organization for Standardization (ISO)
- International Electrotechnical Commission (IEC)
- ISO/IEC Joint Technical Committee 1 (JTC1)
- Electronic Industries Alliance (EIA)
- Institute of Electrical and Electronic Engineers (IEEE)
- International Council on Systems Engineering (INCOSE)
- Software Engineering Institute (SEI)
- Enterprise Process Improvement Collaboration (EPIC)
- Software Process Improvement Capability dEtermination (SPICE) Project
- BOOTSTRAP Institute

The International Organization for Standardization is an organization that promotes international standardization across a broad range of technical and functional areas. “The mission of ISO is to promote the development of standardization and related activities in the world with a view to facilitating the international exchange of goods and services, and to developing cooperation in the spheres of intellectual, scientific, technological and economic activity.”² ISO’s focus is based on standardization’s importance in:

- Advancing trade liberalization
- Adapting to the interdependence of sectors
- Fostering global communications systems
- Defining factors of new technologies
- Improving the position of developing countries³

Each member country is represented in ISO by its national standards body. ISO has been involved in the development of standards and technical reports, the most notable are the ISO 9000 family of standards. This family of standards includes ISO 9000:2000, *Quality management systems—Fundamentals and vocabulary*, ISO 9001:2000, *Quality management systems—Requirements*, and ISO 9004:2000, *Quality management systems—Guidelines for performance improvements*. These documents are globally accepted by organizations for conducting international trade. ISO also develops standards in conjunction with the International Electrotechnical Commission (see pages 10 and 11).

² “Introduction to ISO—What is ISO?,” ISO Web site, <http://www.iso.ch/infoe/intro.html>, 20 November 2000.

³ “Introduction to ISO—Why is International Standardization Needed?,” ISO Web site, <http://www.iso.ch/infoe/intro.html>, 20 November 2000.

International Organization for Standardization (ISO)

- Consists of standards bodies representing each member country
- Promotes standardization for international commerce
- Involved in development of international standards and technical reports, for example
 - ISO 9000:2000
 - ISO 9001:2000
 - ISO 9004:2000

A simplified version of ISO's organizational structure⁴ is illustrated in the accompanying diagram. Within this overall organizational structure, the technical committees (TCs) are the bodies that perform the technical work necessary for the development of a standard. Through a specific technical committee and its hierarchical structure, standards are developed based on consensus, voluntary involvement, and global- and industry-wide solutions.

ISO's 175+ TCs represent specific products and/or industries and perform relevant standardization work. Some examples of TCs are as follows:

- TC 2, Fasteners
- TC 20, Aircraft and space vehicles
- TC 176, Quality management and quality assurance⁵

Each TC performs the technical work for a specific area of interest. This work is accomplished within a hierarchical structure on both the international and national levels. At the international level, this hierarchy consists of subcommittees and working groups, each with their specific focus. At the national-level, each member country has its own representative national body that is responsive to the TC of interest, a national technical advisory group (TAG) linked to a specific SC, and technical groups corresponding to each of the working groups. In the United States, the national body is the American National Standards Institute (ANSI). The accompanying diagram illustrates the ISO TC's international- and national-level components and their interrelationships.

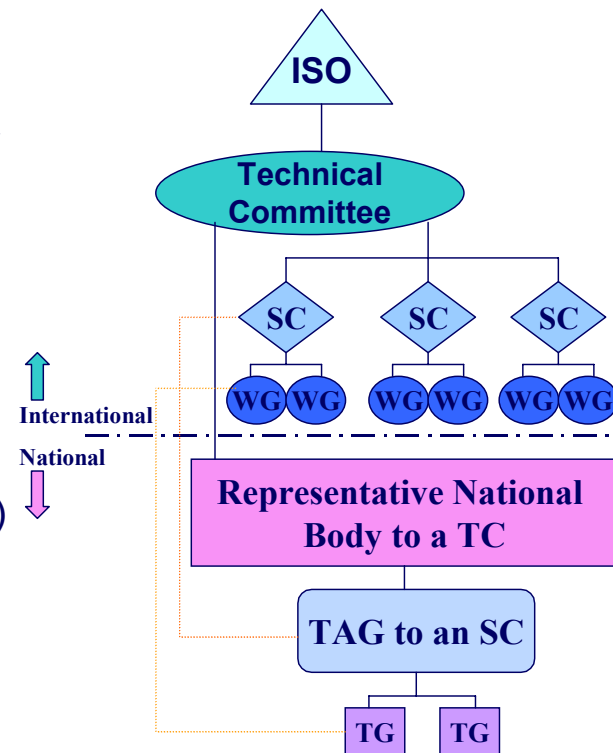
IDA is an active member of the U.S. TAG to TC 176.

⁴ Created from: "ISO's Structure," ISO Web site, <http://www.iso.ch/iso/en/aboutiso/isostruture/isostr.html>, 20 April 2001.

⁵ "List of Technical Committees," ISO Web site, <http://www.iso.ch/iso/en/stdsdevelopment/tc/tclist/TechnicalCommitteeList.TechnicalCommitteeList>, 26 November 2001.

ISO Technical Committee Structure

- 175+ Technical Committees perform ISO's technical work
- Each possesses its own hierarchical structure
 - International level
 - Subcommittee (SC)
 - Working group (WG)
 - National level
 - Technical Advisory Group (TAG)
 - Task Group (TG)



The International Electrotechnical Commission consists of participating countries, each of which “agrees to open access and balanced representation from all private and public electrotechnical interests in its country,” and receives the right to full participation in the preparation and publication of standards.⁶ The IEC’s mission is “to promote, through its members, international cooperation on all questions of electrotechnical standardization and related matters, such as the assessment of conformity to standards, in the fields of electricity, electronics, and related technologies.”⁷ In order to support this mission, the IEC strives to:

- Meet global market requirements in an efficient manner
- Maximize use of its standards and assessment methodologies
- Improve and assess products and services on the basis of their quality
- Set parameters for the interoperability of systems
- Improve the efficiency of industrial processes
- Improve human health and safety
- Protect the environment⁸

ISO and the IEC collaborate on Joint Technical Committee 1 (JTC1), *Information Technology*, which is focused on “standardization in the field of information technology.” Joint life cycle process standards include ISO/IEC 12207: *Information Technology—Software Life Cycle Processes*, ISO/IEC 15288: *Systems Engineering—System Life Cycle Processes*, and ISO/IEC TR 15504: *Information Technology—Software Process Assessment*.

⁶ “Inside the IEC,” IEC Web site, <http://www.iec.ch/gnote1-e.htm>, 30 November 2000.

⁷ Ibid.

⁸ Ibid.

International Electrotechnical Commission (IEC)

- Consists of member countries
- Promotes international cooperation in electrotechnical standardization
- Participates with ISO on Joint Technical Committee 1 (JTC1), *Information Technology*
- Involved in the development of life cycle process standards and technical reports, for example
 - ISO/IEC 12207
 - ISO/IEC 15288
 - ISO/IEC TR 15504

The accompanying diagram shows the hierarchical structure for JTC1, *Information Technology*. JTC1 is divided into 17 SCs according to the specific use and application of information technology within different sectors. The SC of greatest relevance to this document is SC7—*Software and System Engineering*. Presently, the Secretariat of SC7 is held by the Standards Council of Canada and its membership consists of 28 participating countries and 18 observer countries.⁹ Each year, SC7 conducts one international plenary meeting hosted by a member country.

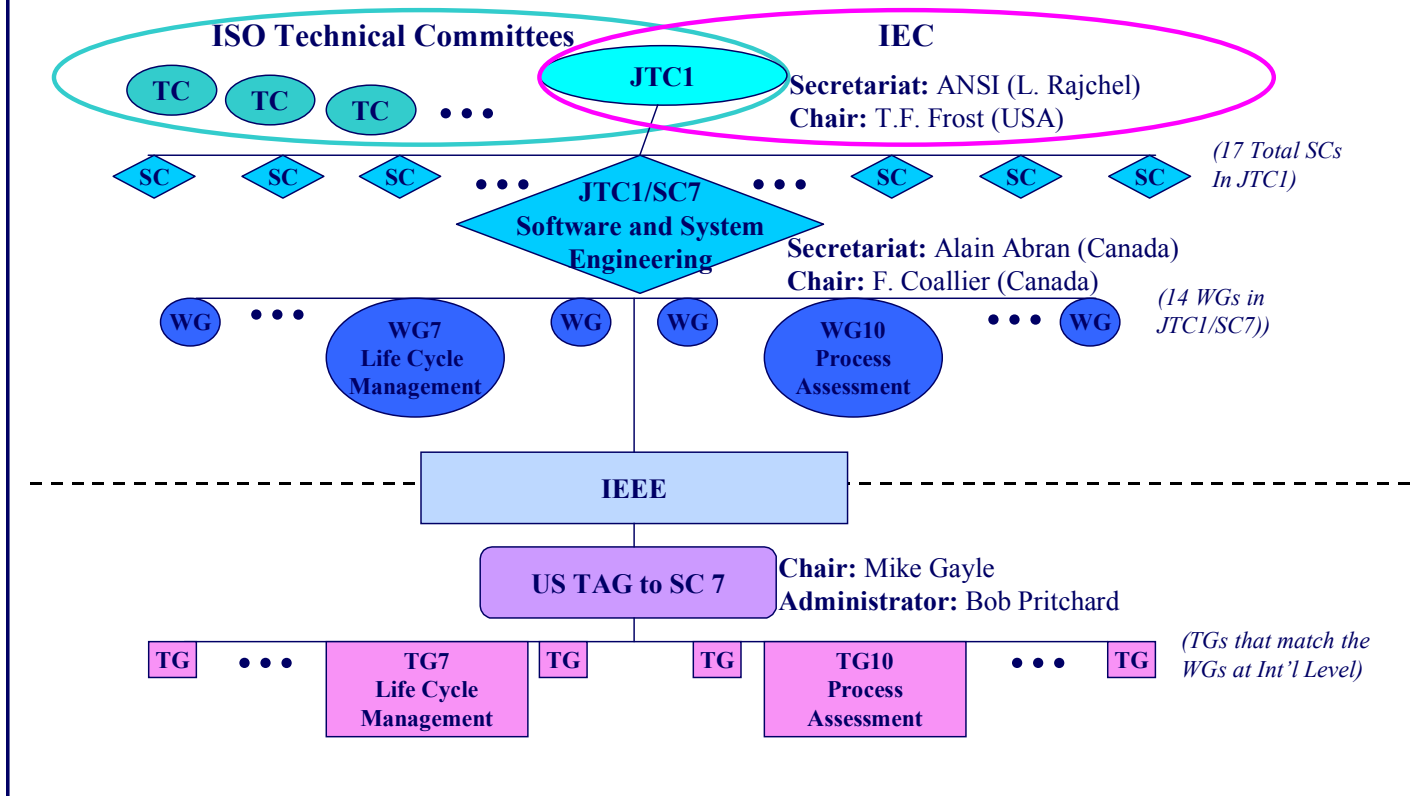
SC7 is divided into 11 working groups (WGs), two of which are of particular importance to this document: WG7, *Life Cycle Management*, and WG10, *Process Assessment*. The convener for WG7 is Doug Thiele of Australia. Alec Dorling of the United Kingdom is the convener for WG 10. Each working group conducts at least two international interim meetings each year in member countries.

The national-level involvement represented in this diagram is that of the United States. The Institute of Electrical and Electronic Engineers (IEEE) is the U.S. member organization to JTC1 SC7. Operationally, the day-to-day work on behalf of the United States is performed by the U.S. TAG, consisting of TGs that correspond to each of JTC1 SC7's WGs. DoD and IDA participate in the U. S. TAG to SC7, *Software and System Engineering*. The work on life cycle process standards and assessments occurs in TG7, *Life Cycle Management*, and TG10, *Process Assessment*. U.S. TAG meetings occur two to three times a year, and each TG has interim meetings as necessary to follow the schedule of required international votes on work products.

IDA is an active member of SC7 and participates in WG7 and WG10 work.

⁹ "JTC1 SC7—Software and System Engineering," ISO Web site, <http://www.iso.ch/en/std...lPage.TechnicalCommitteeDetail?COMMID=40.html>, 26 November 2001.

ISO/IEC/TAG Hierarchy for JTC1



The Electronic Industries Alliance represents the electronics industry through a federation of industry-related sectors and associations.¹⁰ The EIA fosters connections within the electronic industries; projects power and influence in terms of mapping the future of technology and public policy; provides industry and market research, data, analysis, and forecasts; and develops standards important to the electronic industries.¹¹

EIA consists of six autonomous, yet united, associations relevant to the electronic industries. These associations are the Telecommunications Industry Association (TIA), the Consumer Electronics Association (CEA), the Electronic Components, Assemblies and Materials Association (ECA), the Government Electronics and Information Technology Association (GEIA), the JEDEC Solid State Technology Association, and the Electronic Industries Foundation (EIF). The GEIA's Systems Engineering Committee has been instrumental in developing many systems engineering standards.

During the summer of 1994, the EIA established an EIA Working Group, which worked toward the development of EIA Interim Standard (IS) 632:1994, *Processes for Engineering a System*. This standard was the commercial equivalent to MIL-STD-499B, *Systems Engineering*, which was never published due to DoD's move toward the use of commercial standards. The EIA was joined in this effort by the Aircraft Industry Association (AIA), DoD, the National Security Industries Association (NSIA), the Institute of Electrical and Electronic Engineers (IEEE), and the International Council on Systems Engineering (INCOSE). In 1998, EIA 632, *Processes for Engineering a System*, became a full standard. In addition to 632, EIA has developed other standards such as interim standard EIA/IS 731, *Systems Engineering Capability Model (SECM) and Appraisal Method*. The EIA also coordinated with the IEEE on IEEE/EIA 12207:1996: *Standard for Information Technology—Software life cycle processes*.

¹⁰ "Benefits," EIA Web site, <http://www.eia.org/members/benefits/index.cfm>, 30 November 2000.

¹¹ Ibid.

Electronic Industries Alliance (EIA)

- Federation of associations and sectors associated with the electronics industry
- Resource and voice for advancement of the electronics industry
- Involved in development of systems engineering and software engineering standards, for example
 - EIA 632
 - EIA/IS 731
 - IEEE/EIA 12207

The Institute of Electrical and Electronic Engineers draws its membership from professionals and students who are working toward or have already established a certain level of professional competence in the fields of electrical engineering or information technology, e.g., computer engineering, biomedical technology, telecommunications, electric power, aerospace and consumer electronics.¹² The IEEE “helps advance global prosperity by promoting the engineering process of creating, developing, integrating, sharing, and applying knowledge about electrical information technologies and sciences for the benefit of humanity and the profession.”¹³ Interaction among its members and IEEE work can take place by and/or through regional bodies, technical societies, technical councils, society chapters, and sections.

The IEEE Standards Association is an international membership organization that develops and disseminates standards. The IEEE was an original member of the EIA Working Group founded to develop EIA/IS 632:1994, *Processes for Engineering a System*. The IEEE also developed IEEE 1220-1994, *Trial-Use Standard for Applications and Management of Systems Engineering Process*, which later became IEEE 1220-1998, *IEEE Standard for the Application and Management of the Systems Engineering Process*. IEEE coordinated with the EIA on IEEE/EIA 12207:1996, *Standard for Information Technology—Software life cycle processes*.

¹² “Understanding Membership,” IEEE Web site, <http://www.ieee.org/membership/understanding.html>, 26 November 2001.

¹³ “About the IEEE,” IEEE Web site, <http://www.ieee.org/about>, 28 November 2000.

Institute of Electrical and Electronic Engineers (IEEE)

- Professional society
- Promotes the engineering process for electrical and information technologies and sciences
- Involved in development of systems engineering and software engineering standards, for example
 - IEEE 1220
 - IEEE/EIA 12207
 - EIA/IS 632

The International Council on Systems Engineering is a professional organization for industry and government professionals, as well as academics, with knowledge of and experience in systems engineering. “INCOSE is an international authoritative body promoting the interdisciplinary approach and means to enable the realization of successful systems.”¹⁴ In fostering the definition, understanding and practice of systems engineering, INCOSE operates with the following goals:

- Serve as a focal point for the distribution of knowledge
- Encourage collaboration in education and research
- Set standards for professional integrity
- Augment the professional status
- Promote government and industry support for research and education¹⁵

In 1992, INCOSE sponsored the Capability Assessment Working Group (CAWG), which functions within INCOSE’s Measurement Technical Committee. The CAWG was chartered to develop “a method for assessing and improving the efficiency and effectiveness of systems engineering.”¹⁶ The CAWG developed and then released version 1.0 of the *Systems Engineering Capability Assessment Model (SECAM)* and the *SECAM Assessment Method* in February and March 1994, respectively. INCOSE was also involved with the development of EIA/IS 632, *Process of Engineering a System* (as an original member of the EIA Working Group) and involved with EPIC in the development of EIA/IS 731, *Systems Engineering Capability Model (SECM)* and the *SECM Appraisal Method*.

¹⁴ INCOSE Web site, <http://www.incose.org>, 29 November 2000.

¹⁵ “Welcome to INCOSE!— Missions, Goals, and Objectives,” INCOSE Web site, <http://www.incose.org/intro.html>, 26 November 2001.

¹⁶ Systems Engineering Capability Model (SECM), EIA/IS 731.1, vol. 1, p. 1.

International Council on Systems Engineering (INCOSE)

- Professional organization
- Promotes an interdisciplinary approach to systems engineering
- Chartered the CAWG to develop an assessment and improvement method for systems engineering
- Involved in development of systems engineering standards, capability models, and assessment methods, for example
 - EIA/IS 632
 - SECAM
 - EIA/IS 731

The Software Engineering Institute was established by DoD as a federally funded research and development center (FFRDC)¹⁷ because of the importance of quality software, delivered on-time and within budget, to the development and procurement of defense systems. In order to facilitate this relationship between defense systems and software, SEI's mission is to "provide leadership in advancing the state of the practice of software engineering to improve the quality of systems that depend on software."¹⁸ SEI is chartered to:

1. "Bring the ablest professional minds and the most effective technology to bear on the rapid improvement of the quality of operational software in systems that depend on software
2. Accelerate the reduction to practice of modern software engineering techniques and methods
3. Promulgate the use of modern techniques and methods throughout the defense community."¹⁹

During the early 1990s the SEI produced various versions of the Capability Maturity Model for Software (the "CMM"), based on "the" vision of Watt's Humphrey, the first director of the SEI's Software Process Program. An assessment method was also developed for the CMM. In part due to the success of this model, the SEI provided project management and administrative support to EPIC to produce the *Systems Engineering–Capability Maturity Model (SE–CMM)* and the *SE–CMM Appraisal Method (SAM)*, which were released as SEI documents. The SEI produced other capability maturity models (CMMs) and assessment methods, such as the Integrated Product Development (IPD) CMM and the People CMM. The SEI, with government and industry sponsorship, ultimately developed the Capability Maturity Model Integration (CMMI) and its appraisal method.

¹⁷ The specific contract for the SEI FFRDC is held by Carnegie Mellon University.

¹⁸ "About the SEI— Welcome," SEI/Carnegie Mellon Web site, <http://www.sei.cmu.edu/about/about.html>, 27 November 2001.

¹⁹ "The SEI Charter," SEI/Carnegie Mellon Web site, <http://www.sei.cmu.edu/about/overview/sei/charter.html>, 27 November 2001.

Software Engineering Institute (SEI)

- FFRDC associated with Carnegie Mellon University
- Provided program management and administrative support to EPIC
- Involved in development of capability maturity models (CMMs) and assessment methods in four areas:
 - Software
 - Systems Engineering
 - Integrated Product Development
 - People

The Enterprise Process Improvement Collaboration evolved from INCOSE's CAWG, with project management and administrative support provided by the Software Engineering Institute of Carnegie Mellon University. EPIC's focus was on the development of a systems engineering capability maturity model. EPIC released, as SEI documents, the *Systems Engineering–Capability Maturity Model* (SE-CMM) and the *SE-CMM Appraisal Method Description* in December 1994 and March 1995, respectively.

Enterprise Process Improvement Collaboration (EPIC)

- Collaboration of industry, government, and academia
- Focused on the development of a systems engineering capability maturity model
- Involved in development of a capability maturity model and appraisal method
 - SE-CMM
 - SE-CMM Appraisal Method Description

The Software Process Improvement Capability dEtermination (SPICE) project was formed as a major international collaborative effort to develop an international framework standard for software process assessment. The project was carried out under the auspices of ISO/IEC JTC1 SC7 WG10.²⁰ It began unofficially in 1990 and was made official in June of 1993.²¹ It no longer exists as a project, although web sites about it are still available.

The result of the project was Technical Report ISO/IEC TR 15504 (see pages 98–99). “SPICE” has been used to refer to ISO/IEC 15504, although it is not appropriate or accurate to do so.

The Software Quality Institute of Griffiths University in Australia, the Software Engineering Institute (SEI) at Carnegie Mellon University in Pittsburgh, and the European Software Institute (ESI) were all partners in the SPICE project and were heavily involved in the field trials that began in 1995. The ESI uses the assessment model in their Business Improvement Guides.²²

²⁰ Software Quality Institute, Griffith University, Australia, <http://www-sqi.cit.gu>

²¹ SEI SPICE homepage, <http://www.sei.cmu.edu/iso-15504/>

²² <http://www.esi.es/Projects/PI/overview.html>, 12 February 2002.

Software Process Improvement Capability dEtermination (SPICE) Project

- International effort under the auspices of ISO/IEC JTC1 SC7 WG 10
 - Started in 1993
- Purpose to develop a framework standard for software process assessment
 - Resulted in 9-part technical report, ISO/IEC 15504
- SPICE no longer exists as a formal project

The Bootstrap Institute, based in Brussels, is a non-profit organization formed by some of the participating members of the completed European Software Program for Research in Information Technologies (ESPRIT) project.

Although the Institute offers licensing, assessor accreditation, and training and maintains the BOOTSTRAP data base, the Institute's main objectives are the development and promotion of the Bootstrap Methodology. The approach of the Bootstrap Methodology is to “determine by assessment the gap between the current process state and the desired process state for a particular aspect of the business and then to develop an improvement plan from that analysis.”²³ The Bootstrap Methodology is compliant with ISO/IEC 15504, ISO 9000, and the CMM capability levels. Its current release is Version 3.2.²⁴

²³ From the European Software Institute Dictionary, <http://www.esi.es/Help/Dictionary/Definitions/Bootstrap.html>.

²⁴ The Bootstrap Institute home page, <http://www.Bootstrap-institute.com/home.htm>.

Bootstrap Institute

- Non-profit organization that promotes the Bootstrap methodology for software process improvement
- Purpose to service the European software industry to improve its competitiveness
- Offers
 - Licensing
 - Assessor Accreditation
 - Training Curriculum
 - The BOOTSTRAP Data Base

The next section describes six standards for life cycle processes.

Standards for Life Cycle Processes

- Software Life Cycle Processes (ISO/IEC 12207)
- System Life Cycle Processes (ISO/IEC 15288)
- Quality Management Systems—Requirements, ISO 9001:2000
- Application of ISO 9001 to Software, ISO/IEC 9000-3
- Processes for Engineering a System, EIA 632
- Application and Management of Systems Engineering Process, IEEE 1220

ISO/IEC 12207:1995, *Standard for Information Technology—Software Life Cycle Processes*, is the product of ISO/IEC JTC1, SC7, WG7, as described on pages 12 and 13. ISO/IEC 12207 establishes a common framework or architecture for software life cycle processes and is intended to provide engineering discipline to software development and maintenance. The need for a common framework was established by virtue of the increasing incorporation of software into systems and technologies, as well as the existence of multiple standards, procedures, methods, tools, and environments for use in software development. The *Guide for ISO/IEC 12207 (Software Life Cycle Processes)* was published as Technical Report ISO/IEC TR 15271 in 1998.

Since ISO/IEC 12207 was initially released in 1995 and expected to have a lifespan of 25 to 30 years, the need to incorporate changes into it was anticipated in order to maintain the standard’s relevance to industry and the manufacture of software. Accordingly, in July 1999 WG7 released its “Vision 2020” for ISO/IEC 12207. Central to this endeavor was the establishment of a plan for maintaining this standard through 2020, with updates of the standard every 3 to 5 years. The first Proposed Draft Amendment (PDAM) was released in 1999 concurrent with the concept for “Vision 2020.”

WG7 has agreed to a second amendment. A study period has been authorized to harmonize ISO/IEC 12207 with ISO/IEC 15288, which is currently in final draft international standard (FDIS) (see pages 36–39); ISO/IEC 9000-3, which is in committee draft (see pages 4043); and ISO/IEC 15504, which is in various stages of revision (see pages 98–99).

IEEE and EIA jointly agreed to and accepted “clarifications, additions, and changes” to ISO/IEC 12207:1995 and documented these in their own joint standard, IEEE/EIA 12207.0-1996, also referred to as US 12207, which is intended to provide industry with a better understanding of software practices.²⁵

²⁵ IEEE/EIA 12207.0-1996, *Industry Implementation of International Standard ISO/IEC 12207:1995, Standard for Information Technology— Software Life Cycle Processes*, March 1998.

Software Life Cycle Processes

ISO/IEC 12207:1995

- Product of ISO/IEC JTC1, SC7, WG7
- Purpose/Scope
 - Need for this standard
 - Software being incorporated into many systems and technologies
 - Multiple standards, procedures, methods, tools, and environments used for software development
 - Establishes a common framework for software life cycle processes
- Background/Status
 - Initial Release — August 1995
 - 1999 plan for amendment and revision through 2020
 - Harmonization effort underway
 - Study period authorized for revision
 - Second amendment agreed to by WG7

ISO/IEC 12207:1995 consists of processes, activities, and tasks that cover the life cycle of software from conception through retirement and demonstrates the relationships among these processes. The processes contained in ISO/IEC 12207 represent a framework that covers the whole software life cycle. An organization may seek to implement all of the standard's processes or only a subset of those processes selected via the standard's tailoring process to meet the specific software needs of the organization. To successfully perform a process, all of the activities and tasks within that process must be satisfied. When used in a contract, a minimum set of processes, activities, and tasks needs to be established and satisfied in order for a supplier to be in compliance with the standard. ISO/IEC 12207 describes the architecture of the software life cycle processes but does not specify details of how to implement or perform the activities and tasks included in the processes. In general, the "how to" implementation is left to lower-level standards.

The software life cycle processes are captured in three categories—Primary Life Cycle Processes, Supporting Life Cycle Processes, and Organization Life Cycle Processes. The primary processes apply to primary parties, such as the acquirer, supplier, developer, operator, and maintainer involved in developing, operating, or maintaining software. In general, the software life cycle processes are initiated by the Acquisition process. The Supply process responds and initiates the development, operations, or maintenance processes. The support processes are those that contribute to the success and quality of the software project and are "called" by other processes. Finally, the Organizational processes are initiated by an organization to establish, implement, or improve other software life cycle processes.

ISO/IEC 12207:1995 List of Processes

Processes, Activities, and Tasks

Primary Life Cycle Processes

Acquisition Process
Supply Process
Development Process
Operation Process
Maintenance Process

Organizational Life Cycle Processes

Management Process
Infrastructure Process
Improvement Process
Training Process

Supporting Life Cycle Processes

Documentation Process
Configuration Management Process
Quality Assurance Process
Verification Process
Validation Process
Audit Process
Problem Resolution Process

** Annex A— Tailoring Process

After experience was gained in the use of ISO/IEC 12207, it was discovered that the granularity of the process definitions in ISO/IEC 12207:1995 made it difficult to derive a process rating component for the purpose of process assessment and improvement. The Amendment process was started in part to correct this and to provide a process purpose and outcomes so that ISO/IEC 12207 can become a Process Reference Model in accordance with the new requirements of ISO/IEC 15504 (see pages 98–99). Normative Annex F provides the process reference model for the standard and gives the purpose and outcomes for each process in the standard. The Amendment is also in accordance with the architecture of the existing standard, ISO/IEC 12207, and the developing standard, ISO/IEC 15288, *Systems Engineering—System Life Cycle Processes*, which provides a process purpose and outcomes for its life cycle processes.

ISO/IEC 12207:1995 Amendment

- Accommodates requirements of present and developing SC7 standards and reports
- Changes to align with ISO/IEC 15504
 - Resolves granularity of the process definition
 - Provides process purpose and outcomes
- Specific text changes and addition of 3 annexes
 - No longer prohibits ISO/IEC 12207 use for off-the-shelf software
 - Adds text on conformance to purposes and outcomes
 - Annex F: Process Reference Model from ISO/IEC TR 15504 Part 2
 - Clarification that lists of tasks are not “exhaustive”

ISO/IEC 15288, *Systems Engineering—System Life Cycle Processes*, covers the life cycle of a man-made system from concept through retirement. “It provides the processes for acquiring and supplying system products and services that are configured from one or more of the following types of system components: hardware, software, and humans. In addition, the framework provides for the assessment and improvement of the life cycle.”²⁶ This standard is designed to be used by an organization, a project within an organization, or an acquirer and a supplier via an agreement

As of this publication, ISO/IEC 15288 is in Final Draft International Standard (FDIS) form and being balloted. When voted on and passed by two thirds of the member bodies, it becomes an International Standard. This is expected by fall 2002.

An effort is underway to harmonize many of the standards discussed in this document once ISO/IEC 15288 is published. Resolution 629 at the Nagoya SC7 Plenary meeting states:

JTC1/SC7 intends to initiate a revision of ISO/IEC 15288 and ISO/IEC 12207 for harmonization between these standards and also ISO 9000-3 and ISO/IEC TR 15504 as soon as ISO/IEC 15288 and ISO/IEC 12207 PDAM are published. To prepare for this work JTC1/SC7 instructs its WG7 to initiate a study period once a successful FCD and FDAM ballot have been completed.

The SC7 also created an Ad Hoc System Engineering Study Group that surveyed the utility of the systems engineering standards for an organization to implement a systems engineering approach. It determined that an organization would need ISO/IEC 15288, EIA 632 (see pages 48–51), and IEEE 1220 (see pages 52–55). ISO/IEC 15288 defines the processes needed during a system’s life cycle, EIA 632 defines the set of requirements for engineering a system, and IEEE 1220 defines the systems engineering process itself. An approach has been proposed for harmonizing these three documents and making them consistent with each other.

²⁶ ISO/IEC 15288 FCD, Introduction.

Software Life Cycle Processes

ISO/IEC 12207:1995

- Product of ISO/IEC JTC1, SC7, WG7
- Purpose/Scope
 - Need for this standard
 - Software being incorporated into many systems and technologies
 - Multiple standards, procedures, methods, tools, and environments used for software development
 - “Establishes a common framework for software life cycle processes”
- Background/Status
 - Initial Release— August 1995
 - 1999 plan for amendment and revision through 2020
 - Harmonization effort underway
 - Study period authorized for revision
 - Second amendment agreed to by WG7

The processes in ISO/IEC 15288 are grouped into four categories: Agreement, Enterprise, Project, and Technical.

For each process listed, a process purpose and outcomes are given in order to establish a Process Reference Model in accordance with requirements of ISO/IEC 15504-2, *Information technology —Software Process Assessment—Part 2: A Reference Model for Processes and Process Capability*. Activities are also given for each process, but it is the accomplishment of the outcomes that gives evidence that the requirements of an organization's declared set of processes (those that apply to its business objectives) are being met.

A Guide is also being developed for this standard that gives greater detail about implementation of these processes. ISO/IEC TR 19760, *Guide for ISO/IEC 15288 (System Life Cycle Processes)* is currently in ballot for combined WD/PDTR Registration, due 5 June 2002. The intention is for it to be published shortly after the International Standard.

ISO/IEC 15288 FDIS List of Processes

Process Outcomes and Activities

Enterprise Processes

Enterprise Environment
Management
Investment Management
System Life Cycle Processes
Management
Resource Management
Quality Management

Project Processes

Project Planning
Project Assessment
Project Control
Decision Making
Risk Management
Configuration Management
Information Management

Agreement Processes

Acquisition
Supply

Technical Processes

Stakeholder Requirements Definition
Requirements Analysis
Architectural Design
Implementation
Integration
Verification
Transition
Validation
Operation
Maintenance
Disposal

ISO 9001:2000, *Quality Management Systems—Requirements*, is perhaps the best known international standard on the market. This revision of the 1994 version took a process focus, and so, is pertinent to this document. ISO 9001:2000 is also ISO’s “umbrella” publication to which all other ISO standards need to conform in some manner. This is particularly true for vocabulary, which is found in its accompanying publication, ISO 9000:2000, *Quality Management Systems—Fundamentals and Vocabulary*. These ISO vocabulary directives proved difficult to follow in some instances in the development of ISO/IEC 15288. For example, “system” in the sense of a quality management system has a different connotation than “system” in the sense of an aerospace system. Definitions for “verification” and validation” were also established in ISO 9000:2000 and needed to be followed in the development of ISO/IEC 15288. Of necessity, some deviations in definitions were used and these appear in the FDIS of ISO/IEC 15288. How these vocabulary issues are resolved at the ISO level remains to be seen.

Quality Management Systems— Requirements, ISO 9001:2000

- Product of ISO Technical Committee 176
 - Subcommittee 2, Quality Systems
- Purpose
 - “Promotes the adoption of a process approach when developing, implementing, and improving the effectiveness of a quality management system, to enhance customer satisfaction by meeting customer requirements”
- Background/Status
 - Third Edition of International Standard published 13 December 2000

The list of processes in this standard differs from those in the other standards and models described in this document. These processes are associated with a quality management system, whereas the other processes were associated with a part of the life cycle of a system. Still, because of the globally pervasive nature of ISO 9001:2000, most standards and models that organizations choose to use in addition to 9001 will need to map to these processes in some fashion.

ISO 9001:2000 List of Processes

- Management Responsibility
- Resource Management
- Measurement, Analysis, and Improvement
- Product Realization
 - Planning of Product Realization
 - Customer-Related Processes
 - Design and Development
 - Purchasing
 - Production and Service provision
 - Control of Monitoring and Measuring Devices

ISO TC176 coordinated with JTC1 SC7 on the fate of ISO 9000-3:1997, Quality Management Assurance Standards—Part 3: Guidelines for the Application of ISO9001:1994 to Development, Supply, Installation, and Maintenance of Computer Software. TC176 eventually agreed to transfer ISO 9000-3:1997 to SC7 for the creation of the new version to accompany ISO 9001:2000. This new document is currently in Final Committee Draft (FCD) form and out for ballot. It is called ISO/IEC 9000-3, Software and System Engineering—Guidelines for the Application of ISO 9001:2000 to Software. It is currently scheduled for publication in early 2003.

Application of ISO 9001:2000 to Software, ISO/IEC 9000-3

➤ Product of ISO/IEC JTC1 SC7 WG7

➤ Purpose

- “This International Standard provides guidance in applying the requirements of ISO 9001:2000 where computer software design, development, supply, installation and maintenance are elements of the business of an organization”

➤ Background/Status

- Ownership transferred from ISO TC176 to JTC1 SC7
- Final Committee Draft (FCD) out for ballot due May 2002
- Expected publication 1st quarter 2003

Since SC7 is now involved in redoing ISO 9000-3, the product realization processes are aligned with the processes in ISO/IEC 12207.

ISO/IEC 9001-3 List of Processes

- Management Responsibility
- Resource Management
- Product Realization
 - Planning of Product Realization
 - Customer-Related Processes
 - Design and Development
 - Control of Production and Service Provision
 - Validation of Processes
 - Purchasing
 - Customer property
 - Identification and Traceability
 - Preservation of Product
 - Control of Monitoring and Measuring Devices
- Measurement, Analysis and Improvement

The original EIA Interim Standard (IS) 632, *Systems Engineering*, was published by the EIA in December 1994—the result of a working group made up of members from EIA, IEEE, INCOSE, AIA, NSIA, and DoD. This interim standard was the commercialized version of the MIL-STD-499B, *Systems Engineering*. MIL-STD-499B was only published in draft form as it was overcome by the events of DoD’s acquisition reform move to commercial standards. MIL-STD-499B had been drafted by the Air Force System’s Command Directorate of Systems Engineering and the Defense Systems Management College (DSMC) Systems Engineering Department.

Work on the ANSI/EIA 632 standard, *Processes for Engineering a System*, began in 1997 with the intent for it to be the early implementation of systems engineering that would later be covered by ISO/IEC 15288. The processes in EIA 632 describe “what to do” with respect to the processes for engineering a system, which is the next level down from the ISO/IEC 15288 level of system life cycle processes.

INCOSE participated in the creation of this standard with the G47 Systems Engineering committee of the Government Electronic and Information Technology Association (GEIA) of the EIA.

Processes for Engineering a System, ANSI/EIA 632

- Product of ANSI and EIA with INCOSE
- Purpose/Scope
 - “Provide an integrated set of fundamental processes to aid a developer in the engineering and reengineering of a system”
- Background/Status:
 - Initial release—EIA/IS 632, December 1994
 - EIA Working Group (EIA, IEEE, AIA, INCOSE, NSIA, DoD)
 - Commercialized version of MIL-STD-499B
 - ANSI/EIA release in 1998
 - Intended to be early U.S. implementation of systems engineering to be covered by ISO 15288

The processes for engineering a system are divided into five categories: Acquisition and Supply, Technical Management, System Design, Product Realization, and Technical Evaluation. Acquisition and Supply processes are used by the developer to arrive at an agreement with another to accomplish specific work and deliver required products. The Technical Management processes area is used to plan, assess, and control the technical work required to satisfy the established agreement. The System Design processes are used to convert agreed-upon requirements of the acquirer into a set of realizable products that satisfy acquirer and other stakeholder requirements. Product Realization processes are used to convert the specified requirements and other design solution characterizations into either a verified end product or a set of end products in accordance with the agreement and other stakeholder requirements. And, finally, the Technical Evaluation processes are invoked by one of the other processes for engineering a system. These consist of systems analysis, requirements validation, system verification, and end product validation processes.

Each process is described by requirements. The influence of the enterprise and the project are discussed on the application of the processes, as well as the influence of other external factors. The engineering life cycle is also discussed in the context of the project life cycle.

ANSI/EIA 632 List of Processes

Processes and Requirements

Fundamental Processes for Engineering a System

Acquisition and Supply

- Supply
- Acquisition

Technical Management

- Planning
- Assessment
- Control

System Design

- Requirements Definition
- Solution Definition

Product Realization

- Implementation
- Transition to Use

Technical Evaluation

- Systems Analysis
- Requirements Validation
- System Verification
- End Products Validation

IEEE 1220, *Trial-Use Standard for Application and Management of the Systems Engineering Process*, was published on 28 February 1995. The authorized standard was published in 1998, its major differences being greater emphasis on software and on engineering the system for humans. The latter standard simplified the systems breakdown structure, clarified conformance statements, and broke functional analysis into context analysis and functional decomposition for clarity as well.

IEEE 1220 gives the next level of detail below the process requirements described in EIA 632. The processes are described more at the task or application level. IEEE 1220 also does not worry about “who does what” as some of the other standards do with the “acquirer-supplier” concepts.

Application and Management of the SE Process, IEEE 1220: 1998

➤ Product of IEEE

➤ Purpose/Scope

- “Provide standard for managing a system from initial concept through development, and define life cycle disposal”

➤ Background/Status

- Initial release—February 1995 (“Trial-Use Standard”)
- Intent was to merge with EIA/IS 632 to form one ANSI standard, published jointly by EIA, IEEE, and INCOSE
- Most recent release—December 1998 (full, authorized standard)


The processes in IEEE 1220, *Standard for Application and Management of the Systems Engineering Process*, are divided into those for the life cycle and those of the Systems Engineering Process (SEP). The process descriptions provide “interdisciplinary tasks that are required throughout a system’s life cycle to transform customer needs, requirements, and constraints into a system solution.”²⁷

²⁷ IEEE 1220, *Standard for Application and Management of the Systems Engineering Process*, IEEE Computer Engineering Society, Software Engineering Standards Committee, 1998.

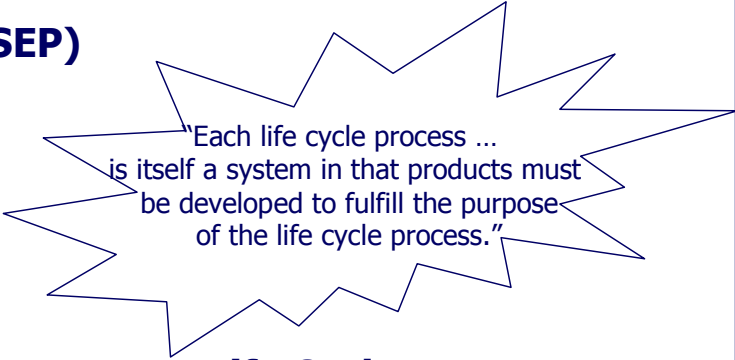
IEEE 1220: 1998 List of Processes

Systems Engineering Process (SEP)

Requirements Analysis
Requirements Validation
Functional Analysis
Functional Verification
Synthesis
Design Verification
Systems Analysis
Control



Apply SEP throughout
system life cycle



Each life cycle process ...
is itself a system in that products must
be developed to fulfill the purpose
of the life cycle process."

Life Cycle Processes

Development
Manufacturing
Test
Distribution
Operation
Support
Training
Disposal

The following section of this document describes capability and maturity models for life cycle processes.

Capability and Maturity Models

- Capability Maturity Model for Software (SW-CMM)
- Systems Engineering Capability Maturity Model (SE-CMM)
- Systems Engineering Capability Model (SECM) (EIA/IS 731.1)
- Integrated Product Development Capability Maturity Model (IPD-CMM)
- Capability Maturity Model Integration (CMMI)
- integrated Capability Maturity Model (iCMM)

The concept of maturity levels originated in the quality and continuous improvement community with Philip Crosby. Beginning in the 1970s, Crosby was one of the “Quality Gurus,” along with J. Edwards Deming and J. M. Juran. Crosby tended to focus on the management responsibility for quality. In his book, *Quality is Free*,²⁸ Crosby describes the improvement process as taking place over five stages: Uncertainty, Awakening, Enlightenment, Wisdom, and Certainty. The models discussed in this section use this concept, although the maturity or capability levels are more specific than these stages.

²⁸ Philip B. Crosby, *Quality is Free: The Art of Making Quality Certain*, McGraw-Hill Book Company, 1979.

Crosby's Quality Management Maturity Stages

- 1. Uncertainty
- 2. Awakening
- 3. Enlightenment
- 4. Wisdom
- 5. Certainty

During the early 1990s, the SEI produced various versions of the Capability Maturity Model® (CMM®)²⁹ for Software, based on the vision of Watts Humphrey, the first director of the SEI's Software Process Program. This model uses a staged representation that has five maturity levels that an organization can achieve in its software process improvement efforts. An assessment framework, model, and method were all developed for the CMM. The appraisal methods are described in the next section of this document. The Software CMM gained wide acceptance and the SEI has collected much information and data on its use and results of its use. Authors include Mark C. Paulk, Bill Curtis, Mary Beth Chrissis, and Charles V. Weber.

When people speak of “the CMM” or the “SEI CMM,” it is this model to which they refer. The current policy in DoD 5000.2 states:

Select contractors with domain experience in developing comparable software systems; with successful past performance; and with a mature software development capability and process. Contractors performing software development or upgrade(s) for use in an ACAT I or ACAT IA program shall undergo an evaluation, using either the tools developed by the Software Engineering Institute (SEI), or those approved by both the DoD Components and the Deputy Under Secretary of Defense (Science and Technology) (DUSD(S&T)). At a minimum, full compliance with SEI Capability Maturity Model Level 3, or its equivalent in an approved evaluation tool, is the Department's goal.³⁰

The Software CMM, Version 2.0 Draft C, was used as a source model for the Capability Maturity Model Integration (CMMI) (see pages 76–79). The SEI will no longer publish any updates to the SW-CMM model or training materials; however, the SEI will offer its course, *Introduction to SW-CMM*, for 2 years after the publication of CMMI V1.1. The SEI will not withdraw the rights of the organizations that are transition partners to deliver the *Introduction to SW-CMM* training beyond the 2-year period to select organizations requesting on-site delivery. New instructors may be authorized, if needed.³¹

²⁹ Capability Maturity Model®, CMM®, Capability Maturity Model IntegrationSM, and CMMISM are registered terms belonging to the SEI and Carnegie Mellon University. For simplicity, they are not always marked as such in this document.

³⁰ DoD 5000.2, Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) And Major Automated Information System (MAIS) Acquisition Programs, June 2001.

³¹ How Will Sunsetting of the Software CMM be Conducted?, SEI Web site, <http://www.sei.cmu.edu/cmmi/comm/sunset.html>.

Capability Maturity Model for Software (SW-CMM)

- Product of SEI
- Purpose/Scope
 - Used by organizations for appraising the maturity of their software processes and for identifying practices that will increase the maturity of those processes
- Background/Status
 - CMM v1.0 released in August 1991, v1.1 in February 1993
 - Version 2.0 Draft C as source document for CMMI
- Staged Representation

The five maturity levels of the CMM for Software are described behaviorally as follows:³²

1. Initial, where processes are performed in an ad hoc manner
2. Repeatable, where discipline is introduced into the processes with policies and procedures
3. Defined, where standard processes are documented
4. Managed, where quantitative quality goals are set for products and processes
5. Optimizing, where the entire organization is focused on continuous improvement

Each Maturity Level has several Key Process Areas associated with it “that indicate the areas an organization should focus on to improve its software process. Key process areas identify the issues that must be addressed to achieve a maturity level.” Each Key Process Area has a set of related activities “that, when performed collectively, achieve a set of goals considered important for enhancing process capability.”³³ These activities are described in terms of goals and key practices.³⁴

³² Paulk, Mark C., Bill Curtis, Mary Beth Chrissis, and Charles V. Weber, *Capability Maturity Model for Software*, Version 1.1, Technical Report, CMU/SEI-93-TR-024, February 1993.

³³ Ibid.

³⁴ Paulk, Mark C., Charles V. Weber, Suzanne Garcia, Mary Beth Chrissis, and Marilyn Bush, Key Practices of the *Capability Maturity Model*, Version 1.1, Technical Report, CMU/SEI-93-TR-025, February 1993.

SW-CMM List of Processes

Goals and Key Practices

Requirements Management
Software Project Planning
Software Project Tracking and
Oversight
Software Subcontract
Management
Software Quality Assurance
Software Configuration
Management

Organization Process Focus
Organization Process Definition
Training Program
Integrated Software Management
Software Product Engineering
Intergroup Coordination
Peer Reviews
Qualitative Process Management
Software Quality Management
Defect Prevention
Technology Change Management
Process Change Management

The Systems Engineering Capability Maturity Model (SE-CMM) is the product of the SE-CMM Project, which comprises individuals from industry, academia, and government under the auspices of the SEI. The industry collaboration on the project became Enterprise Process Improvement Collaboration (EPIC) (see pages 22–23 of this document). The SE-CMM “describes the essential elements of an organization’s systems engineering process that must exist to ensure good systems engineering. In addition, the SE-CMM provides a reference for comparing actual SE practices against these essential elements.”³⁵ Like other CMMs, it does not specify a particular process model or sequence of processes. The model encompasses all phases of the system life cycle and was designed to help organizations “improve their practice of SE through self-assessment and guidance in the use of statistical process control principles.” Use of the model for supplier selection was discouraged.

When the SECM was later released, EPIC no longer supported the SE-CMM, which was merged with the SECAM to form the SECM, EIA/IS 731 (see pages 68–71). Current effort in this area is now part of the CMMI project.³⁶

³⁵ *A Systems Engineering Capability Maturity Modelsm*, Version 1.1, CMU/SEI-95-MM-003, November 1995.

³⁶ <http://www.sei.cmu.edu/cmm/se-cmm.html>

Systems Engineering Capability Maturity Model (SE-CMM)

➤ Product of EPIC

➤ Purpose/Scope

- Describes the essential elements of an organization's systems engineering process that must exist to ensure good systems engineering and encompasses all phases of the product life cycle

➤ Background/Status

- Version 1.0 of SE-CMM released December 1994
- SE-CMM v.1.1 released November 1995
- Merged with the SECAM to create the SECM and no longer supported

The SE-CMM is organized around the process capability aspect, which included the generic practices, and the domain aspect, which included the base practices. The base practices are organized into process areas, which in turn are grouped into Engineering, Organizational, and Project categories. Each process area was ranked at a certain maturity level, based on implementation of the generic practices. The generic practices constituted five capability levels:³⁷

- Level 0 Not Performed
- Level 1 Performed Informally
- Level 2 Planned and Tracked
- Level 3 Well-Defined
- Level 4 Quantitatively Controlled
- Level 5 Continuously Improving

The use of these generic practices made this model function like the continuous representation of later models.

³⁷ *A Systems Engineering Capability Maturity Model*, Version 1.1, CMU/SEI-95-MM-003, November 1995.

SE-CMM List of Processes

Process Areas and Base Practices

Engineering Process Areas

- Analyze Candidate Solutions
- Derive and Allocate Requirements
- Evolve System Architecture
- Integrate Disciplines
- Integrate System
- Understand Customer Needs
- Verify and Validate System

Project Process Areas

- Ensure Quality
- Manage Configurations
- Manage Risk
- Monitor and Control Technical Effort
- Plan Technical Effort

Organizational Process Areas

- Define Organization's Systems Engineering Process
- Improve Organization's Systems Engineering Process
- Manage Product Line Evolution
- Manage Systems Engineering Support Environment
- Provide Ongoing Skills and Knowledge
- Coordinate with Suppliers

EPIC's SE-CMM and INCOSE's SECAM (see pages 102–103) were combined into a single model and assessment method under the auspices of a project charted under the EIA G-47 Systems Engineering Committee. The result of the project was that EIA published the EIA Interim Standard (EIA/IS) 731-1, *Systems Engineering Capability Model (SECM)* and EIA/IS 731-2, *Systems Engineering Capability Model (SECM) Appraisal Method*. Thus, Volume 1 contains the model and Volume 2 is the appraisal method. The model contains Generic Practices and Generic Attributes that are grouped into the four levels of capability above level 1, which contains none.³⁸

1. Performed
2. Managed, where activities are planned and tracked
3. Defined, where activities are performed according a well-defined process using approved versions of standard and documented processes (may be tailored)
4. Measured, where measurement is applied to the processes
5. Optimizing, where quantitative performance goals for process effectiveness and efficiency based on business goals are established

The SECM was originally published as an interim standard by the EIA because it was to be used as a source model for the CMMI (see pages 76–79) and would be canceled once the CMMI was published. Changes in the rules and regulations governing EIA standards has eliminated the “Interim Standard” designation, so it will be published as a full standard.

³⁸ EIA/IS 731.1, *Systems Engineering Capability Model (SECM)*.

Systems Engineering Capability Model (SECM) (EIA/IS 731)

- Product of EIA, INCOSE, and EPIC
- Purpose/Scope
 - “To support the development and improvement of systems engineering capability”
- Background/Status
 - Reflects March 1996 initiative to merge SECAM and SE-CMM
 - Intended to complement the use of EIA 632 and IEEE 1220
 - EIA/IS 731, Draft Version 1.0
- Continuous Representation

The processes in EIA/IS 731 (SECM) are listed within three systems engineering focus areas: Technical, Management, and Environment. Each process has specific practices and generic characteristics associated with it.

EIA/IS 731 (SECM) List of Processes

Focus Areas, Specific Practices, and Generic Characteristics

Systems Engineering Technical Focus Areas

Define Stakeholder and System Level Requirements
Define Technical Problem
Define Solution
Assess and Select
Integrate System
Verify System
Validate System

Systems Engineering Management Focus Areas

Plan and Organize
Monitor and Control
Integrate Disciplines
Coordinate with Supplier
Manage Risk
Manage Data
Manage Configurations
Ensure Quality

Systems Engineering Environment Focus Areas

Define and Improve the Systems Engineering Process
Manage Competency
Manage Technology
Manage Systems Engineering Support Environment

The Integrated Product Development Capability Maturity Model (IPD CMM) grew out of a study of commercial and defense organizations. The study focused on organizations practicing IPD with teams and conducted interviews for good and bad examples of IPD implementation. The study team was searching for IPPD best practices with the benefits gained and the problems confronted in its implementation. The results were compiled in a data base and published by one of the study participants.³⁹

The IPD CMM was used as a source model for the CMMI SE/SW/IPPD model (see pages 76–79). IDA participated in the development of the IPD CMM.

³⁹ Kerinia Cusick, “A Collection of Integrated Product Development Lessons Learned,” *INCOSE Conference Proceedings*, 1997.

Integrated Product Development Capability Maturity Model (IPD-CMM)

- Product of SEI, government, and industry
- Purpose/Scope
 - Provide a requirements framework for establishing, appraising, and improving any organization's product life cycle and supporting processes
 - Provide a common language and resource for IPD concepts
 - Support the adoption of IPD in a wide variety of industries, service operations, government, and academia
- Background/Status
 - Versions in 1996, 1997, 1998
 - Merged into CMMI-SE/SW/IPPD

The process areas in the IPD CMM are grouped into Product Life Cycle, Process Management, and Integration categories. Process Management processes relate to operational efficiency, Integration Processes relate to effectiveness, and both are applied to any system life cycle.

The maturity levels of organizational performance using the IPD CMM are:

1. Performed Informally
2. Planned and Tracked, reducing local chaos
3. Well Defined, defined and tailored processes
4. Quantitatively Managed, managing by facts
5. Continually Improving, optimizing operations

IPD-CMM List of Processes

Purpose, Goals, and Best Practices

Product Life Cycle

Product Selection
Product Life Cycle Definition
Product Requirements Evolution
Solution Design
Product Build, Verification & Test
Product Support and Retirement

Integration

Project Leadership
Leadership Mechanisms
Work Environment
Team Environment
Shared Vision
Organizational Leadership
Product Line Evolution
Organizational Environment Adaptation

Process Management

Process Planning
Configuration Management
Ensuring Quality
Process Monitoring & Control
Organization Training Program
Organization Process Definition
Organization Process Focus
Quantitative Techniques
Process Change Management

The Capability Maturity Model–Integration (CMMI) is actually a framework that can be used to produce various combinations of models based on the disciplines for which models exist. Currently, CMMI models exist for Systems Engineering (SE), Software (SW), and Integrated Product and Process Development (IPPD). Acquisition, safety, security, and modeling and simulation are all additional disciplines that have been investigated for addition to the model suite.

The CMMI model integrates the Systems Engineering, Software Engineering, and Integrated Product and Process Development (IPPD) Capability Maturity Models (CMMs) to provide a framework for process integration and improvement across an organization. The CMMI will be used by both government and industry for self-assessments to increase their process capability and organizational maturity. Since the DoD’s goal is to select contractors with a mature development process and capability, policy implications for a contractor’s use of the CMMI model need to be investigated.

The Software CMM uses a staged representation. The Systems Engineering Capability Model (SECM), EIA/IS 731, uses a continuous representation. In a staged representation, specific process areas are required for each maturity level and an organization gets rated on its maturity. In a continuous representation, the organization chooses the set of process areas that applies to its business objectives and then each process area gets individually assessed to a capability level. The CMMI has both a staged representation and a continuous representation. An Equivalent Staging Diagram published in the CMMI models shows an equivalence between the two representations. To be equivalent to a Maturity Level 3 rating for an organization, it would have to be capability level 3 in all of the process areas listed in diagram.

The maturity levels within the CMMI framework are: 1) Initial, 2) Managed, 3) Defined, 4) Quantitatively Managed, and 5) Optimizing. The capability levels are the same except that a process can be at capability level 0, Incomplete, as well. A maturity level for an organization of “incomplete” does not make sense in the context of the CMMI.

While the CMMI-SE/SW/IPPD model was being developed, a need was perceived for a model version with the “acquisition” discipline added, and an attempt was made to incorporate the Software Acquisition CMM. This effort evolved into a more succinct addition of a supplier sourcing (SS) discipline, to create a CMMI-SE/SW/IPPD/SS model.

Capability Maturity Model- Integration (CMMI)

- Product of SEI with government and industry participation
- Purpose/Scope
 - Combine into a single model for use by organizations pursuing enterprise-wide process improvement
 - SW-CMM v2.0 draft C
 - EIA/IS 731
 - IPD-CMM v0.98
- Background/Status
 - CMMI-SE/SW v 1.0 released August 2000
 - CMMI-SE/SW/IPPD v. 1.01 released November 2000
 - CMMI-SE/SW/IPPD v. 1.1 released January 2002
 - CMMI-SE/SW/IPPD/SS v. 1.1 released March 2002

The CMMI groups processes into four categories: Process Management, Project Management, Engineering, and Support. For each process area, required components are the specific and generic goals and expected components are the specific and generic practices. The required and expected model components are those things that correspond to what is “normative” in standards terminology. The other model components—purpose statement, typical work products, subpractices, amplifications, elaborations, and notes—are all informative material.

The process areas and all required and expected material is exactly the same for CMMI-SW, CMMI-SE, and CMMI-SE/SW. The only difference is that if you were to publish CMMI-SW or CMMI-SE alone, the informative amplifications for the other discipline would not appear. The difference is in informative examples (amplifications) only.

Adding the IPPD discipline to any model adds two process areas (Integrated Teaming and Organizational Environment for Integration) and expands (adds two Specific Goals) to the Integrated Project Management process area.

IDA was a member of the CMMI Integrated Product Team and actively participated in the IPPD, Engineering, Editor, and Framework teams. IDA also served on the CMMI Change Control Board and Steering Group.

CMMI-SE/SW/IPPD List of Processes

Purpose, Goals, and Practices

Project Management Process Areas

Project Planning
Project Monitoring and Control
Supplier Agreement Management
Integrated Project Management
Risk Management
Integrated Teaming
Quantitative Project Management

Engineering Process Areas

Requirements Management
Requirements Development
Technical Solution
Product Integration
Verification
Validation

Process Management Process Areas

Organizational Process Focus
Organizational Process Definition
Organizational Training
Organizational Process Performance

Support Process Areas

Configuration Management
Process and Product Quality Assurance
Measurement and Analysis
Decision Analysis and Resolution
Organizational Environment for
Integration
Causal Analysis and Resolution

The integrated Capability Maturity Model (iCMM) is a product of the Federal Aviation Administration (FAA). “The FAA has been achieving more effective and efficient processes and process improvement by using the FAA integrated Capability Maturity Model® (FAA-iCMM®) to guide its improvement efforts.” The authors include Linda Ibrahim, Bill Bradford, David Cole, Larry LaBruyere, Heidi Leinneweber, Dave Piszczek, Natalie Reed, Mike Rymond, Dennis Smith, Michael Virga, and Curt Wells,

Version 1.0 of the iCMM integrates the CMMs for Software, Systems Engineering, and Software Acquisition. Version 2.0 of the iCMM builds on the integration concept by integrating the following additional standards and models: ISO 9001:2000, EIA/IS 731, Malcolm Baldrige National Quality Award and President's Quality Award criteria, CMMI-SE/SW/IPPD and CMMI-A, ISO/IEC TR 15504, ISO/IEC 12207, and ISO/IEC CD 15288.⁴⁰

The capability Levels are

0. Incomplete
1. Performed
2. Managed, Planned and Tracked
3. Defined
4. Quantitatively Managed
5. Optimizing

⁴⁰ Federal Aviation Administration (FAA), Office of the Assistant Administrator for Information Services and Chief Information Officer (AIO), Process Engineering web site, <http://www.faa.gov/aio/ProcessEngr/iCMM/index.htm#tr>.

integrated Capability Maturity Model (iCMM)

- Product of the Federal Aviation Administration (FAA)
- Purpose/Scope
 - Framework for achieving an enterprise-wide approach to process improvement
- Background/Status
 - Version 1.0 release November 1997
 - Integrated CMMs for Software, Systems Engineering, and Software Acquisition
 - FAA-iCMM V. 2.0, *An Integrated Capability Maturity Model for Enterprise-wide Improvement*, published September 2001

The processes included in Version 2 of the iCMM are shown on the accompanying chart. The 23 processes can be grouped into three categories: Management Processes, Life Cycle Processes, and Support Processes.

FAA iCMM List of Processes

Purpose, Goals, and Base Practices

Management

- Integrated Enterprise Management
- Project Management
- Risk Management
- Supplier Agreement Management
- Integrated Teaming

Life Cycle

- Needs
- Requirements
- Design
- Design Implementation
- Integration
- Deployment, Transition, Disposal
- Operation and Support
- Evaluation

Support

- Outsourcing
- Alternatives Analysis
- Measurement and Analysis
- Quality Assurance and Management
- Configuration Management
- Information Management
- Process Definition
- Process Improvement
- Training
- Innovation

The next section discusses process improvement models that aren't explicitly capability or maturity models.

Process Improvement Models

- Lean Enterprise Model
- Baldrige National Quality Program

The Lean Enterprise Model (LEM) was developed by the Lean Aerospace Initiative. This initiative was formed at the Massachusetts Institute of Technology (MIT) with Air Force sponsorship and industry membership.

Lean Enterprise Model (LEM)

- Product of Lean Aerospace Initiative
- Purpose
 - Framework consisting of lean principles, metrics, and overarching practices
 - Organizational tool for MIT and external information on lean principles and practices from surveys, case studies, and other research activities
- Background/Status
 - Architecture released July 1998
 - On-line tool for members continually updated

The Overarching Practices for the LEM are shown on the chart. Within each Overarching Practice are Enabling Practices.

LEM List of Processes

Overarching Practices with Enabling Practices

- Identify and optimize information flow
- Assure seamless information flow
- Optimize capability and utilization of people
- Make decisions at lowest possible level
- Implement integrated product and process development
- Develop relationships based on mutual trust and commitment
- Continuously focus on the customer
- Promote lean leadership at all levels
- Maintain challenge of existing processes
- Nurture a learning environment
- Ensure process capability and maturation
- Maximize stability in a changing environment

The Baldrige National Quality Program is run by the National Institute of Standards and Technology (NIST).

Baldrige National Quality Program

- Product of the National Institute of Standards and Technology (NIST)
- Purpose/Scope
 - Improve U.S. organizational performance
 - Facilitate sharing of best practices
- Background/Status
 - In existence for 14 years
 - 2002 criteria available now

The Baldrige National Quality Program criteria are arranged in seven categories as shown and detailed below:

1. Leadership
 - Organizational Leadership
 - Public Responsibility and Citizenship
2. Strategic Planning
 - Strategy Development
 - Strategy Deployment
3. Customer and Market Focus
 - Customer and Market Knowledge
 - Customer Relations and Satisfaction
4. Information and Analysis
 - Measurement and Analysis of Organizational Performance
 - Information Management
5. Human Resource Focus
 - Work Systems
 - Employee Education, Training, and Development
 - Employee Well-Being
6. Process Management
 - Product and Service Processes
 - Business Processes
 - Support Processes
7. Business Results
 - Customer-Focused Results
 - Financial and Market Results
 - Organizational Effectiveness Results

Baldrige National Quality Program Criteria

- Leadership
- Strategic Planning
- Customer and Market Focus
- Information and Analysis
- Human Resource Focus
- Process Management
- Business Results

The next section describes the various appraisal, evaluation, and assessment methods that accompany the models covered in the preceding sections.

Appraisal Methods

- Software Process Assessment (SPA)
- Process Assessment (ISO/IEC 15504)
- Capability Maturity-based Appraisal for Internal Process Improvement (CBA IPI)
- Software Capability Evaluation (SCE)
- Software Development Capability Evaluation (SDCE)
- SE-CMM Assessment Method (SAM)
- SECAM
- SECM Appraisal Method (EIA/IS 731.2)
- Standard CMMI Appraisal Method for Process Improvement (SCAMPI)
- FAA-iCMM Appraisal Method (FAM)
- Lean Enterprise Self Assessment Model (LESAT)
- Baldrige National Quality Award

The Software Process Assessment (SPA) is the original assessment method developed by SEI. It was developed in 1987 based on “Characterizing the Software Process: A Maturity Framework” by Watts Humphrey.⁴¹ SEI later commercialized the model in 1990 so that it could be more widely disseminated.⁴²

The SPA predates the Software CMM. When the CMM was released, organizations modified SPA to reflect it, but in 1994 the CBA IPI method (see pages 110–111) was developed and replaced SPA.⁴³

⁴¹ Will Hayes and Dave Zubrow, “Moving on and up: Data and Experience Doing CMM-Based Process Improvement,” (1995), <http://www.sei.cmu.edu/pub/documents/95.reports/pdf/tr008.95.pdf>.

⁴² SCE Version 3.0 Method Description, <http://www.sei.cmu.edu/publications/documents/96.reports/96.tr.002.html>.

⁴³ CBA IPI Method Description, <http://www.sei.cmu.edu/publications/documents/96.reports/96.tr.007.html>.

Software Process Assessment (SPA)

- Product of SEI
 - Original SEI process assessment model
- Purpose/Scope
 - Assessment method based on Humphrey's "Characterizing the Software Process: A Maturity Framework"
 - Used for internal process assessment
- Background/Status
 - Developed in 1987 and commercialized in 1990
 - Predates the CMM
 - SPA has been replaced by CBA IPI

The ISO/IEC Technical Report (TR) 15504, *Software Process Assessment*, is the result of the Software Process Improvement Capability dEtermination (SPICE) project. The TR consists of 9 parts, is based on a process reference model, and follows a continuous representation with capability levels. Field trials of the TR began in 1995 and their results are contributing to the revision of ISO/IEC 15504. Field trials will continue until the full standard is published in the 2003/2004 time frame.

To align with the recent addition of “systems” to the JTC1 SC7 purview, the revision of ISO/IEC 15504 will be titled, *Process Assessment* and will apply to both software and systems assessments. The revision is proceeding as follows:

- | | |
|---|--|
| • 15504-1: <i>Concepts and Vocabulary Assessment</i> (Requirements) | Due February 2004
Due July 2003 |
| • 15504-3 <i>Guidance on Performing an Assessment</i> | Due September 2003 |
| • 15504-4: <i>Guidance on Using the Results of an Assessment Assessment Model</i> | Due December 2003
Due December 2004 |
| | 15504-2, <i>Performing an</i>
15504-5: <i>An Exemplar Process</i> |

The capability dimension of ISO/IEC 15504 contains the following levels:

0. Incomplete
1. Performed
2. Managed
3. Established
4. Predictable
5. Optimizing

Process Assessment (ISO/IEC 15504)

- Product of ISO/IEC JTC1 SC7 WG10
 - Originally sponsored by the SPICE project
- Purpose/Scope
 - Provides a framework for the assessment of software processes and its use in the two contexts of process improvement and process capability determination
- Background/Status
 - Technical Report, 1st edition, published August 1998
 - Software Process Assessment
 - Consists of nine parts
 - Currently in revision to become 5-part full standard for both software and systems

The *Systems Engineering Capability Maturity Model (SE-CMM) Appraisal Method*, or SAM, “provides a description of the appraisal method developed for use with the SE-CMM when evaluating adherence to the principles and/or practices of the SE-CMM. It also contains the appraisal method requirements.”⁴⁴

This appraisal method accompanies the SE-CMM model (see pages 64–67).

⁴⁴ *SE-CMM Appraisal Method Description*, SECMM-94-06 CMU/SEI-94-HB-05.

SE-CMM Appraisal Method (SAM)

➤ Product of EPIC

➤ Purpose/Scope

- Provides a description of the appraisal method for the SE-CMM when evaluating adherence to its principles and practices. It also contains the appraisal method requirements.

➤ Background/Status

- Version 1.0 of SE-CMM Appraisal Method (SAM) released June 1995
- SE-CMM Appraisal Method v.1.1 released 1996

At the same time that EPIC was developing the SE-CMM, INCOSE was developing the SECAM. The SECAM consisted of a questionnaire to be used with both ANSI/EIA 632, *Processes for Engineering a System*, and IEEE 1220, *Application and Management of the Systems Engineering Process*.

There is a model associated with the SECAM that is organized around 19 Key Process Areas (KPA's). These KPA's are in the Technical, Management, and Environment areas of Systems Engineering. Although modeled after the SW-CMM, this model added some non-process areas of concentration.

Systems Engineering Capability Assessment Model (SECAM)

- Product of INCOSE Capability Assessment Working Group (CAWG)
- Purpose/Scope
 - Address assessment of systems engineering capability
 - Used systems engineering standards (IEEE 1220 and EIA/IS 632) as a basis for a questionnaire
 - Used and modified the approach of the CMM for Software
 - Modification consisted primarily of adding questions about product effectiveness and team experience as well as a few other non-process topics
- Background/Status
 - Version 1.5 released July 1996
 - Merged with the SE-CMM to create the SECM and no longer supported

Volume 2 of EIA/IS 731 contains the Appraisal Method, developed by the EIA G47 SECM Working Group that developed EIA/IS 731.1, the SECM model. The method, like the model, was the result of an initiative to merge the SE-CMM (pages 6466 and 100–101) and the SECAM (pages 102–103). It is helpful for industry-wide baselines and comparisons for benchmarking systems engineering processes.

The EIA/IS 731 appraisal method is based on a continuous architecture, as opposed to the appraisal methods associated with the Software CMM (CBA IPI and SCE, see pages 110–113), which are based on a staged architecture. The intent of the EIA/IS 731.2 SECM Appraisal Method is to support self-improvement rather than an official evaluation or audit. The continuous architecture is especially conducive to self-improvement within the organization's business strategy. The method involves comparing the organization's processes with the focus areas, and specific and generic practices of the EIA/IS 731.1 SECM.

SECM Appraisal Method (EIA/IS 731.2)

- Product of EIA, INCOSE, and EPIC
- Purpose/Scope
 - “To support the development and improvement of systems engineering capability”
- Background/Status
 - Reflects March 1996 initiative to merge SECAM and its Assessment Method with that of SE-CMM and its Appraisal Method
 - Intended to complement the use of EIA 632 and IEEE 1220
 - EIA731, Draft Version 1.0

The CMM Appraisal Framework (CAF) was developed by the SEI to identify the requirements and desired characteristics of a CMM-based appraisal method. The framework was designed to ensure that the CMM-based appraisals were consistent and reliable. CAF version 1.0 was published in February 1995 as Capability Maturity Model-based Appraisal for Internal Process Improvement (CBA IPI) Method Description 4. The Software CMM version 1.1 is the associated reference model.⁴⁵

Both the CBA IPI and SCE (pages 110–113) version 3.0 were designed to be CAF compliant, which means that their results should be consistent.

⁴⁵ CAF Version 1.0, 3, <http://www.sei.cmu.edu/publications/documents/95.reports/95-tr-001/95-tr-001-abstract.html>.

CMM Appraisal Framework (CAF)

- Product of SEI
- Purpose/Scope
 - Identifies the requirements and desired characteristics of a CMM-based appraisal method
 - CMM Version 1.1 is associated reference model
 - Similar to ARC for CMMI
 - CBA IPI and SCE both CAF compliant
- Background/Status
 - CAF Version 1.0 published February 1995

The IDEAL model is an improvement model that was developed by SEI to aid organizations in improving their software processes. It is named for the five phases that an organization following this model would go through: **I**nitiating, **D**iagnosing, **E**stablishing, **A**cting, and **L**earning. Many of the services that SEI provides follow the IDEAL model.⁴⁶

⁴⁶ SEI Web site, The Ideal Model, <http://www.sei.cmu.edu/ideal/ideal.html>.

IDEAL Model

- Life cycle model for continuous software process improvement
- Consists of 5 Phases: Initiating, Diagnosing, Acting, Establishing, and Leveraging
- IDEAL strategy is used in many of SEI's services

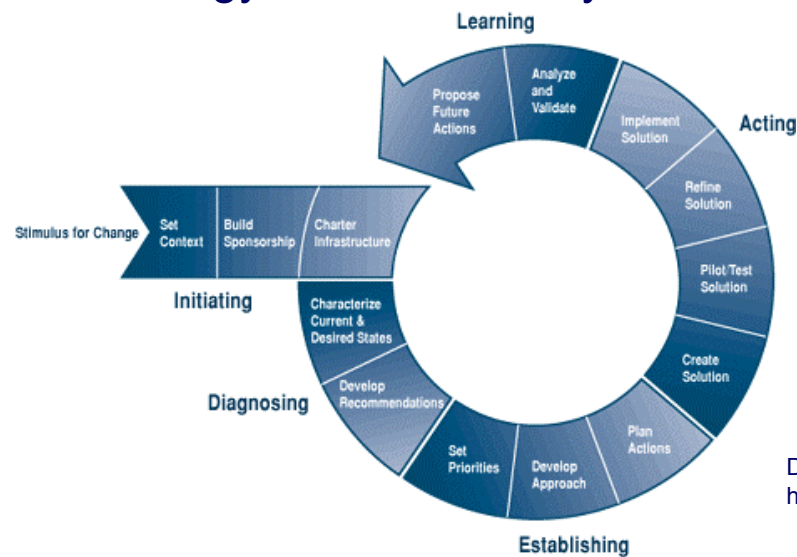


Diagram copied from SEI Web site
<http://www.sei.cmu.edu/ideal/ideal.html>

CBA IPI (Capability Maturity Model-based Appraisal for Internal Process Improvement) is a CMM-based assessment method that was developed by SEI.⁴⁷ It is a method designed to determine and improve the state of one's own processes, as opposed to the Software Capability Evaluation (SCE, pages 112–113) that is intended for use when evaluating another organization's processes.⁴⁸

CBA IPI is CAF (CMM Appraisal Framework) compliant, which means that it adheres to the standards required for a CMM-based appraisal. CBA IPI also uses the IDEAL approach for process improvement.

The first version of CBA-IPI (Version 1.0) was published in May 1995 in response to user needs for a CMM-based appraisal method. Before CMM and the CBA-IPI method, organizations used the SPA (Software Process Assessment) method (pages 96–97) to assess their software processes. After the CMM was published in 1991, organizations modified the SPA method to reflect CMM, but CBA-IPI was the first SEI-developed assessment based on the CMM. The CBA-IPI method was updated to Version 1.1 in March 1996.⁴⁹

⁴⁷ CBA IPI Method Description, <http://www.sei.cmu.edu/publications/documents/96.reports/96.tr.007.html>

⁴⁸ SEI website, "SEI Appraiser Program," www.sei.cmu.edu/managing/app.directory.html.

⁴⁹ Ibid., 4.

Capability Maturity Model – based Appraisal for Internal Process Improvement (CBA IPI)

- Product of SEI
- Purpose/Scope
 - Developed in response to user needs for a CMM-based assessment method
 - CMM-SW Version 1.1 is its reference model
 - Used for assessments of one's own processes (as opposed to SCE)
 - Uses IDEAL approach
 - CAF (CMM Appraisal Framework) compliant
- Background/Status
 - Version 1.0 released in 1995
 - Version 1.1 released in 1996

The Software Capability Evaluation (SCE), developed by SEI, is an evaluation method used for software acquisition. The most recent version, 3.0, reflects CMM Version 1.1.⁵⁰ It is currently one of the two assessment methods that are approved evaluation tools for contractor selection under ACAT 1 Acquisition Policy.⁵¹

SCEs are used to determine the state of another organization's process, rather than one's own processes, although they may be used internally to prepare for an external evaluation.⁵²

The most recent version (Version 3.0) of the SCE method was published in 1996. The original version was described in *A Method for Assessing the Software Engineering Capability of Contractors* (1987), which was developed to support supplier selection for government software acquisition. The evolution of CMM and CAF led to SCE Version 1.5 (July 1993), and the method was later updated to comply with CMM Version 1.1 in SCE Version 2.0 (June 1994).⁵³

⁵⁰ *CBA IPI Method Description*, p. 4.

⁵¹ Jack Ferguson, "DoD Acquisition Policy and SEI CMM Level 3" (presentation), DTIC Web site, <http://www.dtic.mil/ndia/systems/Ferguson2.pdf>.

⁵² SEI Web site, "SEI Appraiser Program," www.sei.cmu.edu/managing/app.directory.html.

⁵³ Ibid.

Software Capability Evaluation (SCE)

- Product of SEI
- Purpose/Scope
 - Developed to support source selection in major government software acquisition and also used for evaluation of internal processes
 - Used to determine the state of another organization's processes (as opposed to CBA IPI)
 - Version 3.0 is CAF compliant
- Background/Status
 - First version described in *A Method for Assessing the Software Engineering Capability of Contractors*
 - SCE Version 3.0 is latest version, published in April 1996

SDCE was developed by ASC/EN based on two other assessment methods, SCE and ASC/EN Software Development Capability/Capacity Review. The evaluation method was initiated in 1992.⁵⁴

As described in Pamphlet 63-103,⁵⁵ the evaluation comprises two parts: the model and the application process. The model contains six functional areas: Program Management, Systems Engineering, Software Engineering, Quality Management and Product Control, Organizational Resources and Program Support, and Program Specific Technologies. These are further broken into Critical Capability Areas (CCAs), and then Critical Capabilities, which are made up of open-ended questions and criteria.⁵⁶

Application of SDCE is fully integrated into the source selection process. SDCE is used to evaluate the contractors' abilities to develop the software defined in the specific Request for Proposal (RFP).⁵⁷

SDCE is currently one of the two assessment methods that are approved evaluation tools for contractor selection under ACAT 1 Acquisition Policy.⁵⁸

⁵⁴ Philip Babel. "Software Development Capability Evaluation: An Integrated Systems and Software Approach," section heading: *Objectives*, <http://www.stsc.hill.af.mil/crosstalk/1997/apr/development.asp>.

⁵⁵ AFMC Pamphlet 63-103, Volumes 1 and 2, *Software Development Capability Evaluation*, 15 June 1994.

⁵⁶ Ibid., section heading: *Model*.

⁵⁷ "SDCE" Software Consortium Web site, <http://www.software.org/quagmire/descriptions/sdce/asp>.

⁵⁸ Jack Ferguson, Briefing, *DoD Acquisition Policy and SEI CMM Level 3*, DTIC Web site, <http://www.dtic.mil/ndia/systems/Ferguson2.pdf>.

Software Development Capability Evaluation (SDCE)

- Product of Aeronautical Systems Center Engineering Directorate (ASC/EN)
- Purpose/Scope
 - Purpose is to reduce acquisition risk for software-intensive systems
 - SDCE is conducted as a part of the source selection process
- Background/Status
 - Effort began 1992
 - Result of merger between SCE and the ASC/EN Software Development Capability/Capacity Review
 - Pamphlet 63-103 describing SDCE published in 1994

The *Appraisal Requirements for CMMI (ARC)* provides a set of criteria for developing, defining, and using assessment methods based on the CMMI model.⁵⁹ ARC appears to be analogous to the CAF, which identifies requirements and characteristics of CMM-based assessments. ARC defines three different classes of assessments, A, B, and C, where A is the most rigorous assessment and C is a “quick look.”⁶⁰

⁵⁹ CMMI Version 1.1, <http://www.sei.cmu.edu/cmmi/products/models.html>.

⁶⁰ ARC Version 1.0, chapter 3, <http://www.sei.cmu.edu/publications/documents/00.reports/00tr011.html>.

Appraisal Requirements for CMMI (ARC)

- Product of SEI
 - Authored by CMMI Product Team
- Purpose/Scope
 - Defines requirements considered essential to appraisal methods intended for use with CMMI models
 - Defines appraisal classes based on appraisal usage scenarios
- Background/Status
 - Version 1.0 released August 2000
 - Version 1.1 released December 2001

The *Standard CMMI Appraisal Method for Process Improvement (SCAMPI)* is a product of the SEI, developed by the Assessment Method Integrated Team (AMIT). SCAMPI is a method that meets all the Class A assessment requirements for CMMI defined by ARC version 1.0.⁶¹ SCAMPI uses the IDEAL approach for process improvement. This approach consists of 5 phases: Initiating, Diagnosing, Establishing, Acting and Learning.⁶²

SCAMPI is based on two earlier assessment methods, CBA IPI version 1.1 and EIA/IS 731.2.⁶³

The first version of SCAMPI (version 1.0) was published in October 2000. The Assessment Method Integrated Team (AMIT) evolved the model to version 1.1, which was published by the SEI in December 2001. The SEI will no longer publish updates to the CBA IPI or the SCE. “CBA IPI Lead Assessors and SCE Lead Evaluators will be trained through December 2003; however, authorized Lead Assessors and Lead Evaluators will need to transition to SCAMPI Lead AssessorsSM within 2 years of the termination of CBA IPI and SCE Lead Assessor/Evaluator training. SCAMPI will then be the appraisal method of choice.”⁶⁴

⁶¹ *SCAMPI Method Description*, p. 3.

⁶² *Ibid.*, 2

⁶³ *SCAMPI Method Description*, p. xi.

⁶⁴ How Will Sunsetting of the Software CMM be Conducted?, SEI Web site, <http://www.sei.cmu.edu/cmmi/comm/sunset.html>.

Standard CMMI Appraisal Method for Process Improvement (SCAMPI)

➤ Product of SEI

- Authored by Assessment Method Integrated Team (AMIT)

➤ Purpose/Scope

- Provides approach to conduct an in-depth class A assessment satisfying all assessment requirements for CMMI (ARC version 1.0)
- Based on CBA IPI Version 1.1 and EIA/IS 731.2
- Uses IDEAL approach

➤ Background/Status

- SCAMPI Version 1.0 published in 2000
- Scampi Method Definition Document V. 1.1 published December 2001

The FAA-iCMM Appraisal Method (FAM) provides the “appraisal method for comparing processes being practiced by an organization to those in the iCMM.”⁶⁵ The authors include Linda Ibrahim, Larry LaBruyere, Pete Malpass, John Marciniak, Art Solomon, and Chuck Weigl. The FAM also includes five variations of the method to meet various appraisal needs. The total of 6 appraisal methods include:⁶⁶

- Standard, full internal FAM framework appraisal, similar to CBA-IPI
- Facilitated discussion
- Document-intensive
- Questionnaire-based
- Interview-based
- Full external evaluation

⁶⁵ <http://www.faa.gov/aio/ProcessEngr/iCMM/index.htm>

⁶⁶ Linda Ibrahim, “Smart Buying with the Federal Aviation Administration’s Integrated Capability Maturity Model,” *Crosstalk*, Vol. 11, No. 11, November 1998, pp. 1520.

Linda Ibrahim, “Using an Integrated Capability Maturity Model—The FAA Experience,” *Proceedings of the Tenth Annual International Symposium of the International Council on Systems Engineering (INCOSE)*, Minneapolis, Minnesota, July 2000, pp. 643648.

FAA-iCMM Appraisal Method (FAM)

- Product of the Federal Aviation Administration (FAA)
- Scope
 - Full appraisal method for processes being practiced to the iCMM
 - Five variations to satisfy various appraisal needs
- Background/Status
 - Version 1.0 released April 1999

The Lean Enterprise Self-Assessment Tool (LESAT) was developed by the Lean Aerospace Initiative for the purposes of enterprise self-assessment. It is produced in two volumes: the Guide and the Maturity Matrices.

Lean Enterprise Self- Assessment Tool (LESAT)

- Product of Lean Aerospace Initiative
- Purpose/Scope
 - Enterprise-level self-assessment
 - Two volumes
 - LESAT Guide
 - LESAT Maturity Matrices
- Background/Status
 - Developed and field-tested over 18 months
 - Version 1.0 released August 2001

The Baldrige National Quality Award is based on an assessment of the Baldrige Criteria shown on pages 9293. The maximum points that can be awarded are shown below, for a maximum possible total score of 1000 points.

1. Leadership	120 points
2. Strategic Planning	85 points
3. Customer and Market Focus	85 points
4. Information and Analysis	90 points
5. Human Resource Focus	85 points
6. Process Management	85 points
7. Business Results	450 points

Baldrige National Quality Award

- Product of the National Institute of Standards and Technology (NIST)
 - Administered with the American Society for Quality (ASQ)
- Purpose/Scope
 - Foster success of the Baldrige National Quality Program
 - Improve U.S. competitiveness
 - Winners share information in annual conference
- Background/Status
 - In existence for 14 years

LIST OF ACRONYMS AND ABBREVIATIONS

ACAT	Acquisition Category
AIA	Aircraft Industry Association
AMIT	Assessment Method Integrated Team
ANSI	American National Standards Institute
ARC	Appraisal Requirements for CMMI
ASC/EN	Aeronautical Systems Center Engineering Directorate
CAF	CMM Appraisal Framework
CAWG	Capability Assessment Working Group
CBA IPI	Capability Maturity Model-based Appraisal for Internal Process Improvement
CD	Committee Draft
CMM	Capability Maturity Model
CMM-SW	Capability Maturity Model for Software
CMMI	Capability Maturity Model–Integration
DoD	Department of Defense
DUSD	Deputy Under Secretary of Defense
EIA	Electronic Industries Alliance
EPIC	Enterprise Process Improvement Collaboration

ESPRIT	European Software Program for Research in Information Technologies
FAA	Federal Aviation Authority
FCD	Final Committee Draft
FDAM	Final Draft Amendment
FDIS	Final Draft International Standard
IDEAL SM	Initiating, Diagnosing, Establishing, Acting and Learning model
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
INCOSE	International Council on Systems Engineering
IPD	Integrated Product Development
IPD-CMM	Integrated Product Development Capability Maturity Model
IS	Interim Standard
ISO	International Organization for Standardization
JTC	Joint Technical Committee
LAI	Lean Aerospace Initiative
LEM	Lean Enterprise Model
LESAT	Lean Enterprise Self-Assessment Tool
MIL-STD	Military Standard

MIT	Massachusetts Institute of Technology
NIST	National Institute of Standards and Technology
NSIA	National Security Industries Association
PDTR	Proposed Draft Technical Report
SC	Subcommittee
SCAMPI	Standard CMMI Appraisal Method for Process Improvement
SCE	Software Capability Evaluation
SE	Systems Engineering
SEI	Software Engineering Institute
SEP	Systems Engineering Process
SPA	Software Process Assessment
SPICE	Software Process Improvement Capability dEtermination
SW	Software
TAG	Technical Advisory Group
TC	Technical Committee
TG	Technical Group
TR	Technical Report
WD	Working Draft

WG	Working Group
Model Names	
ANSI/EIA 632	Processes for Engineering a System
EIA/IS 731	Systems Engineering Capability Model (SECM), Interim Standard
iCMM	Integrated Capability Maturity Model
IEEE 1220	Application and Management of the Systems Engineering Process
IEEE/EIA 12207	Industry Implementation of International Standard ISO/IEC 12207:1995
ISO 9000:2000	Family of Standards encompassing ISO 9000, ISO 9001, ISO 9004 and ISO 19011
ISO 9000:2000	Quality Management Systems—Fundamentals and Vocabulary
ISO 9001:2000	Quality Management Systems—Requirements
ISO 9004:2000	Quality Management Systems—Guidelines for Performance Improvement
ISO 19011	Guidelines for Auditing Quality and Environmental Management Systems
ISO/IEC 12207	Information Technology—Software Life Cycle Processes
ISO/IEC 15288	Systems Engineering—System Life Cycle Processes
ISO/IEC TR 15504	Information Technology—Software Process Assessment, Technical Report
ISO/IEC 15504	Information Technology—Process Assessment
SAM	SE-CMM Assessment Method
SDCE	Software Development Capability Evaluation

SE-CMM	Systems Engineering–Capability Maturity Model
SECAM	System Engineering Capability Assessment Model
SECM	Systems Engineering Capability Model (EIA/IS 731)
SW-CMM	Capability Maturity Model for Software
US 12207	Industry Implementation of International Standard ISO/IEC 12207:1995 (same as IEEE/EIA 12207)

BIBLIOGRAPHY

A Systems Engineering Capability Maturity ModelSM, Version 1.1, SECMM-95-01, CMU/SEI-95-MM-003, November 1995.

ANSI/EIA 632, *Processes for Engineering a System*, Version 1.1, Draft 4, 7 September 1998.

Armstrong, James R. (SMDC) and Arthur Pyster (Software Productivity Consortium), “Resolved: Software Should Lead in Systems Engineering.”

Arter, Dennis R., “The Standards Development Process,” *Quality Progress*, pp. 65–69, July 1999.

Babel Philip, “Software Development Capability Evaluation: An Integrated Systems and Software Approach,”
<http://www.stsc.hill.af.mil/crosstalk/1997/apr/cevelopment.asp>.

Baldrige National Quality Program, *Criteria for Performance Excellence*, 2002.

Barbour, Rick, *Software Capability Evaluation, Version 3.0*, Implementation Guide for Supplier Selection, CMM-Based Appraisal Project, Technical Report CMU/SEI-95-TR-012, April 1996.

Boyd, Austin W., “Best Practices, Metrics and Cost-Benefit for Systems Engineering Process Improvement,” briefing on SAIC study for NASA, August 2001.

Byrnes, Paul, and Mike Phillips, *Software Capability Evaluation, Version 3.0*, Method Description, CMM-Based Appraisal Project, Technical Report CMU/SEI-96-TR-002, April 1996.

CMM-Based Appraisal for Internal Process Improvement (CBA IPI): Method Description, CMU/SEI-96-TR007.

CMMI-SE/SW v.1.02 to SW-CMM v. 1.1 Mapping, STSC, Air Force, 2001.

Conwell, Candace L., Rosemary Enright, and Marcia A. Stutzman, “Capability Maturity Models Support of Modeling and Simulation Verification, Validation, and Accreditation,” *Proceedings of the 2000 Winter Simulation Conference*.

Daniels, Susan E., "The Future of Standards: Problem or Solution," *Quality Progress*, pp. 27–32, July 1999.

Demonstrated Reference Model for SC7 Processes, Draft 7, 8 March 1999.

Draper, Geoff, and David Kitson, "The Development of SCAMPI V1.1," SEPG Conference, Phoenix, AZ, 21 February 2002.

Dunaway, Donna K., and Steve Masters, *CMM-Based Appraisal for Internal Process Improvement (CBA IPI)*, Version 1.2 Method Description, CMU/SEI-2000-TR-033, November 2001.

EIA/IS-632, *Systems Engineering*, December 1994.

EIA/IS-731.1, *Systems Engineering Capability Model (SECM)*, Volume 1, 1994.

EIA/IS-731.2, *Systems Engineering Capability Model (SECM) Appraisal Method*, Volume 2, 1994.

"Feedback on ISO 9001:2000: Worldwide round-up of early market reactions," ISO Management Systems, January-February 2002.

Ferguson, Jack, and Hal Wilson, "DoD Acquisition Policy and SEI CMM Level 3," Software Evaluation IPT Co-leads, ODUSD(S&T) Software Intensive Systems, briefing charts, 25 October 2000.

Ferguson, JoAnn, and Sarah Sheard, "Leveraging Your CMM Efforts for IEEE/EIA 12207," *IEEE Software*, September/October 1998.

Forsberg, Kevin, and Harold Mooze (Center for Systems Management), "Application of 'Vee' to Incremental and Evolutionary Development," INCOSE 95 Proceedings CD.

Hammerslag, David, "Practical Experience with a CMMI Appraisal," Motorola General Business Information, 2002.

Hartmann, Ralf, et al. (Dornier Satellitensysteme GmbH), "The System Engineering Process Definition as Part of the European Cooperation for Space Standardization (ECSS)," INCOSE 98 Proceedings CD.

IEEE Trial-Use Standard for Application and Management of the Systems Engineering Process, IEEE Std 1220-1994, February 1995.

Integrated Product Development Capability Maturity Model (IPD-CMM), v 0.94, Model Overview, briefing, March 1997.

Introduction to the CMMI(SM) Course, Instructor Authorization Process, 6 August 1999.

IPD-CMM Volume 96, April 1997.

ISO 9000 Introduction and Support Package: *Guidance on ISO 9001:2000 clause 1.2 “Application*, 13 Feb 2002.

ISO Handbook, *ISO 9000 for Small Businesses*, Draft, 27 June 2001.

ISO/CD 10006, *Quality Management Systems—Guidelines for Quality Management in Projects*, 16 November 2001.

ISO/IEC 15504, Parts 1-5, in review, 2002.

ISO/IEC TR 15504, Parts 1-9, 1998.

ISO/TR 10017, *Guidance on Statistical Techniques for ISO 9001-2000*, 30 Nov 2001.

Johnson, Donna L., and Judith G. Brodman, “Applying CMM Project Planning Practices to Diverse Environments,” *IEEE Software*, July/August 2000.

Johnson, Kent A., and Dindo, Joe, “Expanding the Focus of Software Process Improvement to Include Systems Engineering,” *Crosstalk*, 1998, <http://www.stsc.hill.af.mil/crosstalk/1998/oct/johnson.asp>.

Kayuha, Bob, CMMI Tutorial, 4 August 1999.

Konrad, Mike, and Tim Kasse, “CMMI Champions: Why CMMI?” SEPG 2002, Phoenix, AZ, February 2002.

Lake, Jerome G., “Report on Development of ISO Standard 15288 System Life Cycle Processes.,” INCOSE 97 Proceedings CD.

Lake, Jerome G., “Thoughts About Life Cycle Phases,” INCOSE 97 Proceedings CD.

Lake, Jerome G., “V&V in Plain English,” *Proceedings of the Ninth Annual International Symposium of the International Council on Systems Engineering (INCOSE)*, 6-10 June 1999, Brighton, England.

Lake, Jerome G., Comparison of Processes and Activities of ANSI/EIA 632 and ISO/IEC 15288 CD3.

Lamprecht, James, “Is ISO 9001:2000 the Beginning of the End?,” *Quality Progress*, July 1999.

Lean Enterprise Model (LEM), MIT, 4 November 1996.

Mah, Michael, “Conversation with Watts Humphrey, SEPG Conference, Phoenix, AZ, February 2002.

Malone, Thomas W., Kevin Crowston, Jintae Lee, and Brian Pentland, “Tools for Inventing Organizations: Toward a Handbook of Organizational Processes,” MIT, in Proceedings of the 2nd IEEE Workshop on Enabling Technologies Infrastructure for Collaborative Enterprises, Morgantown, WV, 20-22 April 1993.

Malpass, Pete, “Integrated Product Development Capability Maturity Model,” v .0.96, Model Overview, April 1997.

Martin, James N. (Raytheon Systems Co.), “Overview of the EIA 632 Standard: Processes for Engineering a System,” INCOSE 98 Proceedings CD.

———, “Evolution of EIA 632 from an Interim Standard to a Full Standard,” INCOSE 98 Proceedings CD.

Masters, Steve and Carol Bothwell, *CMM Appraisal Framework*, Version 1.0, Technical Report CMU/SEI-95-TR-001, February 1995.

MIL-STD-499B, *Systems Engineering, An OSD/Tri-Service/Industry Product*, briefing, 14 October 1992.

Moore, James (MITRE), and David H. Kitson (CMU), “Toward a Common Reference Process Model for SC7,” 21 January 1999.

Moore, Jim, “ISO 12207 and Related Software Life-Cycle Standards, <http://www.acm.org/tsc/lifecycle.html>.

———, “Overview of the Stages in Developing a JTC1 Standard,” 20 January 1999.

Morrison, Arthur F. (Boeing Defense & Space Group), and Brian W. Mar (University of Washington), “Initial System Verification and Validation Considerations.”

Paulk, Mark C., Bill Curtis, Mary Beth Chrissis, and Charles V. Weber, “Capability Maturity Model for Software, Version 1.1,” Carnegie Mellon University, CMU/SEI-93-TR-24, ESC-TR-93-177, February 1993.

Paulk, Mark, “XP from a CMM Perspective,” IEEE Computer Society *Dynabook*,
<http://www.computer.org/SEweb/Dynabook/PaulkCom.htm>.

Process Classification Framework, developed by the International Benchmarking Clearinghouse, 1995.

Report of the Defense Science Board Task Force on Defense Software, November 2000.

Revision to the Interpretation Process for ISO 9001:2000, 22 February 2002.

Royce, Walker, “CMM vs. CMMI: From Conventional to Modern Software Management,” *The Rational Edge*, February 2002.

SC7 Harmonization Activities, 20012002.

Schlichter, John, “Organizational Project Management Maturity Model: Emerging Standards,” briefing, Project Management Institute, Inc., 2001.

SEI IPD-CMM (VO.96)/CMMI, Suggestions for Improvement, briefing, Dayton Aerospace Inc., 16 June 1997.

Servello, Mark, and Mogilensky, Judah, A Frank Discussion of CMMI Models: The Loyal Opposition, or the Pro-Choice Side, SEPG 2002 Conference, Phoenix, AZ, 22 Feb 2002.

Sheard, Sarah A., “Evolution of the Frameworks Quagmire, *Computer*, pp. 96-98, July 2001.

———, “Systems Engineering for Software and Hardware Systems: Point-Counterpoint,” INCOSE 98 Proceedings CD.

———, “The Frameworks Quagmire, A Brief Look,” INCOSE 97 Proceedings CD.

———, “The Frameworks Quagmire,” September 1997.

———, “Twelve Systems Engineering Roles,” presented at the 1996 INCOSE Symposium.

Sheard, Sarah A., and Garry J. Roedler, “Interpreting Continuous-View Capability Models for Higher Levels of Maturity,” *Systems Engineering*, Volume 2, Number 1, 1999.

Sheard, Sarah A., and Jerome G. Lake, “Systems Engineering Standards and Models Compared,” INCOSE 98 Proceedings CD.

———, Systems Engineering Standards and Models Compared, 5 August 1998.

Sheard, Sarah A., Lykins, Howard, and Armstrong, James R., “Overcoming Barriers to Systems Engineering Process Improvement,” Software Productivity Consortium, http://www.software.org/pub/ExternalPapers/sepi_barriers.html.

Software Engineering Process, Lockheed Martin, Engineering Process Improvement (EPI) Software Subcouncil, LM21 Best Practices Program.

Software Life Cycle Processes, IEEE/EIA 12207.0-1996, Industry Implementation of International Standard (ISO/IEC 12207: 1995), ISO/IEC 12207, Standard for Information Technology, March 1998.

Software Life Cycle Processes—Implementation Considerations, IEEE/EIA 12207.0-1996, Industry Implementation of International Standard (ISO/IEC 12207: 1995), ISO/IEC 12207, Standard for Information Technology, April 1998.

Software Life Cycle Processes—Life Cycle Data, IEEE/EIA 12207.0-1996, Industry Implementation of International Standard (ISO/IEC 12207: 1995), ISO/IEC 12207, Standard for Information Technology, April 1998.

Software Process Maturity Questionnaire, Version 1.1.0, CMU, 1994.

Transition Planning for CMMI: Workshop Participants Workbook, 17-18 January 2002.

Transitioning to CMMI: A Guide for Executives, Version 0.4, September 2001.

Velman, J.R. (Hughes Space and Communications Co.), and E.R. Widmann (Raytheon Systems Co.), “Standards: Their Significance, Uses, and Potential Meaning to the Systems Engineering Community,” INCOSE 98 Proceedings CD.

Web-Based Library for Your Business Processes, Process Asset Library (PAL), Lockheed Martin, Business Process Management System.

Widmann, E.R. (Raytheon Systems Co.), “Key Features of the “Merged” EIA/IS 731-1 Systems Engineering Capability Model,” INCOSE 98 Proceedings CD.

Wilson, Steven R., “The Impact of Standards on Industrial Development and Trade,” *Quality Progress*, pp. 71–75, July 1999.

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